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ACTA RADIOLOGICA

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VOL. XXV FASC. 3 30 : VI 1944 N:o 145

CINEMATOGRAPHY IN CEREBRAL ANGIOGRAPHY[1]

by

Olov Fr. Holm

The idea of roentgen cinematography was conceived a short time after the discovery of the roentgen rays. JOHN MACINTYRE, in 1897, is reported by KAESTLE, RIEDER and ROSENTHAL, and REYNOLDS, to have showed a roentgen film 40 feet long illustrating the movements of a frog's hind legs. Other workers (JANKER), however, pointed out that it does not appear from the records whether MACINTYRE really showed the film or only mentioned the possibility of doing so.

Meanwhile, the film was not a true film, but synthetic, being composed of a large number of ordinary roentgenograms of the leg in different positions, which were then arranged so that they seemed to show the movements of the leg.

Experimentation with various systems for changing cassettes made it possible to secure more and more plates per second. A number of different workers studied this problem independently of one another, including EYKMAN (1909), CARVALLO (1909), KAESTLE, REIDER and ROSENTHAL. The last three succeeded in producing serial plates at the rate of one a second showing the movements of the stomach (1909).

Gradually the two methods currently used, the direct method and the indirect method, were evolved.

With the direct method, the picture is made directly on roentgen film, either on a reel or on a large number of standard-size films, which are exposed at short intervals by means of a special device for changing the cassettes.

The workers whose names are primarily associated with the direct method are GROEDEL and PORSCHER, JANKER (1931), and VAN DE MAELE

[1] This study was aided by a grant from the Rockefeller Foundation. Submitted for publication March, 1944.

From the Department of Roentgenology of Serafimerlasarettet, Sweden (Chief: Dr. ERIK LYSHOLM).

(1938) and PIGORINO (1939). Advocates of the method claim that it is superior to the indirect method because a lower roentgen intensity can be used, because standard-size, clear images are secured, and because cheaper apparatuses can be employed.

With the indirect method, the pictures on a fluorescent screen are photographed with a film camera and thus are recorded indirectly on an ordinary photographic film, which should preferably be sensitized to the greenish light given off by the screen.

According to VAN DE MAELE, the indirect method was discovered in 1926 by LOMON and COMANDON, but as early as 1913 L. G. COLE described an apparatus, which can be regarded as a precursor of the apparatuses now used for indirect cinematography. The basic principle of COLE's apparatus was the intermittent unreeling of photographic film in contact with a fluorescent screen. The pictures secured in this way were thus contact copies, unlike those made nowadays, which are reproduced on the film by means of an objective. Credit for the development of the indirect method is mainly due to LUBOSHEZ, JANKER, REYNOLDS, and BÖHME, et al.

Using this method, various workers have secured records of practically all the organs and organic functions accessible to the roentgen rays.

The following examples of more complicated investigations may be mentioned: Examination of the heart by means of combined electrocardiography, roentgen cinematography and ionometry (JANKER 1931); cinematography of the heart combined with sound film of the heart tones (WATANOBE, 1938; KAWAISHI, 1938); cinematography of the heart with the patient exposed to hydrostatic action and during balneotherapy (WILLBALD, 1939), etc. As early as 1926, EUGENIO MILANI transmitted images obtained on the fluorescent screen by television.

In 1940, Dr. LYSHOLM at Serafimerlasarettet in Stockholm began to work on roentgen cinematography, using the indirect method exclusively. Later his investigations were continued by the writer under his direction. We started out with a 16-mm. film camera, but the pictures it gave were too small and coarse-grained. In the autumn of 1941 we changed over definitively to a specially constructed camera with standard-size film. The apparatus (Fig. 1) consist of a film camera with a fluorescent screen attached to it. This unit — film camera-fluorescent screen — is mounted on a stand on which it can be raised or lowered and can be rotated a good 90 degrees in both directions. The stand, which is on wheels, can be moved about at will. The film camera is run by an electric synchromotor and can be adjusted for 4 or 8 or 16 pictures per second, and also for 32. A Zeiss Biotar T lens with an aperture of 1: 0.85 is employed.

A number of different investigations have been conducted with the above apparatus at the Roentgen Department of Serafimerlasarettet.

The chief problem on which I have been engaged is the practicability of roentgen cinematography in cerebral angiography, and I shall now proceed to give an account of my investigations. As far as I know, no other studies of this kind have hitherto been published.

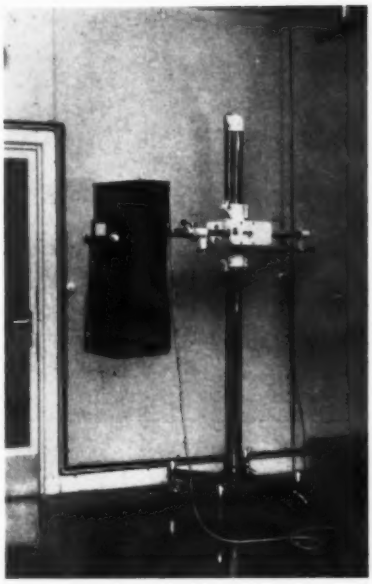

Fig. 1. The film camera and the fluorescent screen, mounted together to form a single unit carried on a stand.

When filming cerebral angiography, the patient is put on his back on a throchoscope with his head above the lower tube. The bifurcation of the carotid artery is exposed in the usual manner. The camera is then rolled up and the focusing is done with the help of the fluorescent screen. Exposure is begun at the same time as the contrast fluid is injected. We used a speed of 8 or, more often, 16 frames a second, the latter representing an exposure time of 0.05 seconds per frame. The tube bears a charge of 100 Kv. with 100 ma. Both thorotrast and perabrodil have been used as contrast media. It has been claimed on various occasions that perabrodil is not suitable for cerebral angiography. We found it quite satisfactory, however, the only difference we noted being that the vessels on the images were somewhat narrower than with thorotrast, indicating vascular contraction. Consequently we generally use thorotrast in patients over fifty years, and also when we have reason to suspect the presence of arteriosclerotic or angiospastic conditions, so as to avoid the vascular contraction caused by perabrodil.

In order to study the behaviour of contrast medium when injected into a vascular system with circulating fluid, we constructed a schematic model of the cerebral vascular system. For this purpose I designed a standard arteriogram on the basis of about ten normal arteriograms. This drawing, in which the caliber of the vessels was reduced to correspond to the roentgenologic enlargement, was transferred to a sheet of plexiglass on which the vessels were engraved to a depth corresponding to the diameter of the vessels. A second sheet of plexiglass was then glued over the first one. In this way the model lay in one plane only, and thus was highly schematic. Nevertheless the method allows for the inclusion of many more vascular branches than any other, and the bi-

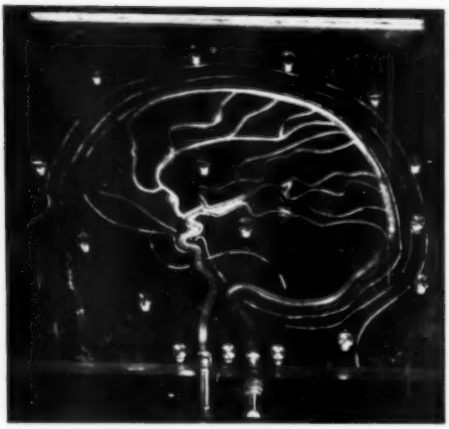

Fig. 2. Schematic model of the cerebral vascular system. The model consists of a plate of plexiglass, on which the vessels are engraved to a depth corresponding to their diameter, according to composite picture secured from 10 normal arteriograms. A second plate of plexiglass is pasted and screwed on to the first one.

furcations can be made entirely smooth, which is not the case when tubes are jointed together to simulate vessels. Another important advantage is that it provides a system without vascular walls to be visualized on the roentgenograms. If tubes made of different materials are employed, it is impossible entirely to avoid a certain roentgen density in the actual vascular wall, which greatly complicates the study of the narrowest bands of medium which pass along the vascular walls. With the plexiglass arrangement, even the thinnest lines of medium can be observed. Figure 2 shows the model itself, and Figure 3 consists of a frame from a cinematography representation of the model, in which the whole system is filled with contrast fluid.

The model is used as follows: physiologic salt solution is allowed to pour through the model from a height of about one meter, and the contrast fluid is injected into a tube leading to the model at the same time as a cinematographic exposure is made. We use either introne or thorotrast as contrast media, and the model is placed either horizontally, or vertically, as in Figure 4. Examination of the images reveals that the most anterior and posterior parts of the contrast medium are drawn out in hair-fine points and therefore cannot be fixed at definite places on the images, and that the medium does not blend properly with the circulating fluid, passing mainly along the basal vascular wall, where the rate of circulation is slower than in the center of the vessel. Hence, attempts to determine the speed of circulation of the medium gave only approximate values. With this reservation, the following values may be mentioned: With the model in the horizontal position the foremost part of the medium, whether introne or thorotrast, passed through the whole model in 0.5 seconds. With regard to the lattermost part of the medium, introne passed through in 3.5 seconds and thorotrast in 4.25 seconds. With the model in the vertical position, as in Figure 4, the following figures were secured for introne: foremost part of the con-

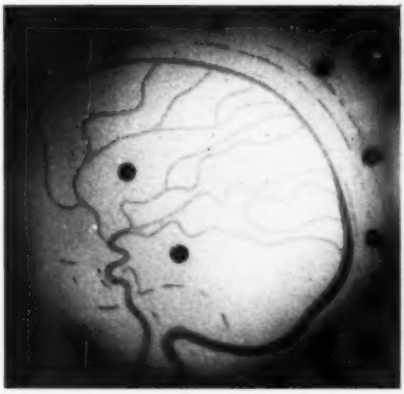

Fig. 3.

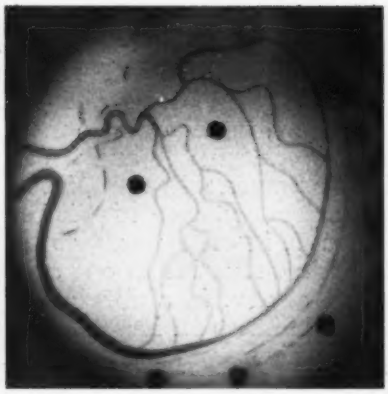

Fig. 4.

Fig. 3. A single frame from a cinematographic record of the model, in which the whole vascular system is filled with contrast medium.

Fig. 4. The model is in the vertical position. Here the contrast medium passes fairly rapidly from the "carotid artery" to the "sinus rectus", where it stagnates, thereby prolonging the time taken for circulation.

trast, 0.8 seconds; lattermost, about 11 seconds. In these experiments the plates were made at a rate of 16 per second.

These experiments could be elaborated upon in several respects; for example, by varying the viscosity of the circulating fluid and the rate of circulation, by increasing the number of exposures per second, etc. Work is now being done along these lines. However, the simple experiment described above, which disclosed that the perfusion rate of the contrast medium varies with different media and different positions of the model, despite the constant speed of the circulating fluid, would seem to prove that *an estimation of the rate of the passage of contrast medium through a vascular system reveals nothing of the physiologic circulation.*

The foregoing appears to correspond with S. R. KJELLBERG's investigations, which mainly concerned phlebographs, where the circulation rate is lower, as well as experiments with a model heart made of glass, by means of which he showed that roentgen cinematography cannot be used to determine the following points:

1. The exact site of the foremost part of the pillar of contrast fluid in a vessel or in the heart.
2. The exact moment when contrast medium enters a ventricle.
3. The distance covered by the contrast medium-blood in a certain period of time.

Meantime, we found by examining cinematographic records of cerebral angiography that the contrast medium appears to behave on the whole in the same way in man as in our model.

For the purpose of studying cinematographic exposures of cerebral angiography, the film can be made up into a band and run through the projector continuously and the images studied as long as desired. For scientific purposes, however, it is probably more useful to examine each frame separately, comparing it in detail with the preceding and succeeding frames, in other words, to treat the film as a series of pictures in immediate succession to one another.

Furthermore, in a sketch, the course of the contrast medium can be filled in image for image. The values secured in this way for the rate of the medium's passage from the internal carotid artery to the jugular vein give no indication of the physiologic rate of circulation of the blood, but certain standard values for the passage of medium can be secured; these values, however, probably vary with different media. I have not been able to establish any such difference in man, probably because the head and tail of the pillar of contrast medium cannot be distinguished distinctly enough.

The following standard values for the passage of contrast medium may be mentioned:

Arterial phase	$^1/_4$ second
Capillary phase	$2\,^1/_4$ »
Venous phase	$1\,^3/_4$ »

The entire course from the internal carotid artery to the jugular vein thus takes 3.25 seconds.

Referring to what has been said as to the difficulty of clearly distinguishing the anterior and posterior parts of the medium, the above values are relatively uncertain; nor is our material extensive enough to permit of any definitive calculations. Nevertheless, I consider them worthy of mention, since the figure, 3.25 seconds, corresponds well with the time chosen arbitrarily in ordinary angiography as a suitable interval between the first picture, the arteriogram, and the second picture, the phlebogram.

Cerebral angiography was evolved by Egas Moniz, who in 1931 produced the first arteriograms of cerebral vessels in man. Since then cerebral angiography has gained steadily in importance, and with the introduction of thorotrast as a contrast medium it came into wide use. At present it is an indispensable method of examination, which is practised almost daily at the Roentgenologic Department of Serafimerlasarettet, even though it entails a surgical intervention for the patient and even though we have not yet succeeded in finding a contrast medium that

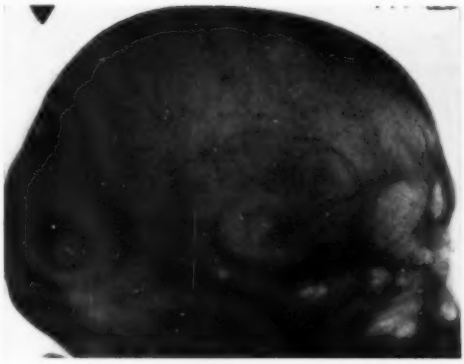

Fig. 5.

Fig. 6.

Fig. 5. Frame from a cinematographic record of normal angiography in man.
Fig. 6. Frame from a cinematographic record of malignant glioma in man. The image shows a part of the arterial phase, but the contrast fluid is already beginning to collect in the posterior parietal region.

is both without risk to the patient as well as fully satisfactory from a diagnostic point of view.

Cerebral angiography establishes the diagnosis and thereby often determines the operative indications in arterial aneurysm and thrombosis, in vascular deformities, such as arteriovenous aneurysm, and in malignant glioma.

Meanwhile, the method used up to the present has certain fundamental disadvantages. First, the contrast medium passes very rapidly through the vessels. In order to record the course of the fluid as accurately as possible, it is desirable to make a number of exposures in rapid succession. With our method of ordinary angiography, we secure two exposures, the first one when the arterial system is completely filled with medium, which point is reached when two cubic centimeters are left in the syringe, on the condition that the injection consists of 7 cc., an amount which has been found suitable. The second exposure is made about three seconds later, at which time the venous system is generally well filled. In addition, a device for changing the cassettes has been constructed, which permits of as many as six exposures of an angiographic examination.

However, not even as many as six exposures visualize the whole course of the medium. This can only be done cinematographically, a method which is obviously superior to roentgenography for the registration of a rapid course.

Fig. 7.

Fig. 8.

Fig. 7. Frame from the same record as in Figure 6, but showing the arterial-capillary phase. One can see the "parenchymatous" loading in the tumor, which is thus visible almost in its entirety, as well as the wide pathologic veins, which are filled with contrast fluid, while medium still remains in the arteries, due to the arterovenous fistulas.

Fig 8. Frame from the same record during the venous phase. The medium still remains in the pathologic veins in the tumor, but in the rest of the cerebral vessels has passed over into the coarser peripheral veins and the sinuses.

It is primarily in cases of arteriovenous aneurysm and malignant glioma that cinematography of cerebral angiography may be expected to yield valuable information, since it is more important to visualize all the phases of the course run by the contrast medium in this type of morbid condition than in others. The passage takes place so rapidly in arteriovenous aneurysm that there is a danger that the first exposure in ordinary angiography be made too late. If cinematography is used, however, the medium can be seen directly as it enters the afferent vessel and a reliable record can be made of the whole phase, which is of great importance in laying plans for the operation. Extirpation is, of course, the only effective form of treatment, and detailed knowledge of the topography is essential for such an intervention.

In malignant glioma, the examiner can follow the course of the contrast medium through the pathologic vessels, and can form an opinion of their extent. He can also observe how the medium passes through the arteriovenous fistulas to the irregularly distended veins, so that the latter become filled at an early stage, and he can see how the medium remains an abnormally long time in these wide veins even after all the medium in the veins beyond the tumor has completely disappeared. Furthermore, careful study of the film permits the examiner to select

the exposures showing the phases in the course that best illustrate the most characteristic changes.

Figure 5 shows a single frame from a cinematographic record of a normal angiography in the arterial phase, and Figure 6—8 shows the arterial, the arterial-capillary and the venous phase in a case of malignant glioma.

In cinematography, less contrast medium is required than in ordinary roentgenography. If too much medium is used, both arteries and veins are visualized at the same time for a relatively long period, which complicates diagnosis. When thorotrast is employed, it is of the greatest importance to reduce the quantity, since LINDGREN and EKSTRÖM reported in 1939 that in some cases thorotrast is retained in the cerebral arteries and may give rise to malacia. In addition, thorotrast is not excreted by the body, but is deposited in the reticulo-endothelial system, where it may do harm, possibly because of its radioactivity.

In ordinary angiography, the minimum amount of contrast fluid is determined by the coordination between the moment of injection and of exposure, that is, by the difficulty of determining the right moment for the exposure in relation to the injection. The longer time the injection takes and the more medium is injected, the longer may be the period during which the exposure can be made and still yield satisfactory results.

With as little as 5 cc., the results are so uncertain that it is sometimes necessary to repeat the process and inject further medium. The most satisfactory quantity for ordinary angiography has been found to be 7 cc., while 3 cc. is quite sufficient for cinematography.

There is still another field in which cinematography might well be very useful, namely, circulatory disturbances of general or local character. So far, however, this field remains unexplored. Although, as already mentioned, values for the normal circulation of the blood cannot be secured with the method under discussion, it is possible to calculate the normal values for the circulation of the contrast medium. Probably, therefore, circulatory disturbances could be recorded by noting deviations from these normal values on the plates, and this could apply to the whole period of time required by the circulation from the carotid artery to the jugular vein, or within a certain vascular area. However more extensive material than is now available to us would be required to permit an investigation along these lines.

We thus find that roentgen cinematography of cerebral angiography is in many respects fundamentally superior to ordinary roentgenography. Will this method be able to replace entirely the earlier methods?

It is still too early to answer this question on the basis of our studies at Serafimerlasarettet. The technical difficulties have been enormous,

and not all of them have yet been solved. The greatest has been to secure sufficiently clear pictures.

The objectives used by us give a clear reproduction only within a central zone about 15 cm. in diameter, which is characteristic of all Zeiss Biotar lenses. Even though the most essential details are situated within this central zone, there are always other details of interest outside it, which therefore are not reproduced with sufficient clarity. The picture we want to reproduce measures 24×30 cm.

Another factor of great importance to the sharpness of the pictures is the grain of the materials used. The film we employ is Agfa fluorapid, which is not particularly fine-grained. In addition, the fluorescent screens must be very sensitive to light, which means that they are quite coarse-grained. As a result the grain of the picture corresponds approximately with the finer arterial branches to be reproduced.

We have recorded cases of small saccular aneurysms of the a. carotis, which on ordinary roentgenograms were approximately pea-sized, but which could not be definitely diagnosed on the film due to lack of clarity. In order to facilitate a comparison between the results of the two methods, we also took ordinary roentgenograms of all the cases recorded cinematographically.

On the basis of our experience with the material available at Serafimerlasarettet, I should like to state as follows: Cinematography of cerebral angiography theoretically is superior to ordinary roentgenography. As a rule it gives a definite diagnosis, and in many cases it has contributed to or verified a diagnosis considered uncertain on the basis of ordinary photography. With the technical resources now at our disposition, however, the time is not yet ripe to replace the older method with the newer one; instead the two should be used to complement each other.

SUMMARY

A brief review of the literature is followed by a description of the apparatus and method used at Serafimerlasarettet in cinematography of cerebral angiography. The writer stresses the advantages of the method in question. The results obtained prove that the method is helpful in diagnosis but that, with the technical equipment now available, it cannot entirely replace ordinary roentgenography.

ZUSAMMENFASSUNG

Auf eine kurze Literaturübersicht folgt die Beschreibung einer im Serafimerkrankenhause verwendeten Apparatur und Methode zur Kinematographie bei zerebraler Angiographie. Verf. betont die Vorzüge der infragestehenden Methode. Die erzielten Ergebnisse zeigen, dass die Methode bei der Diagnosestellung Dienste leistet, dass sie aber mit der heutzutage zugänglichen technischen Ausrüstung die gewöhnliche Röntgenaufnahme nicht vollständig ersetzen kann.

RÉSUMÉ

Un bref rappel de la littérature est suivi de la description de l'appareil et de la méthode en usage au Serafimerlasarettet pour la cinématographie de l'angiographie cérébrale. L'auteur souligne les avantages de la méthode en question. Les résultats obtenus prouvent qu'elle est une aide au diagnostic, mais qu'avec l'équipement technique aujourd'hui disponible elle ne saurait remplacer complètement la radiographie.

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DAS STILLEN — EINE FEHLERQUELLE DER CHOLEZYSTOGRAPHIE

Bemerkungen zur Arbeit von O. Olsson in Acta Radiologica. Vol. XXIV, S. 489, 1943

von

F. Polgár

Ich bin in der Lage die Annahme des obengenannten Verfassers, wonach das Tetrajodphenolphthaleinnatrium durch die Brustdrüse ausgeschieden werden kann, durch folgende einwandfreie Beobachtung bestätigen zu können.

Bei einer 25jährigen, seit 4 Monaten stillenden Frau wurde im August 1943 eine perorale Cholezystographie vorgenommen, wobei das ungarische Präparat *Jodcholin* zur Anwendung kam. Als die Kranke vormittag, 15 Stunden nach Einnahme des Kontrastmittels zur Untersuchung erschien, berichtete sie etwas bestürzt, dass ihre Milch bereits in den frühen Morgenstunden *blaugefärbt war!* Infolge dessen enthielt sie sich des Stillens. Die Absonderung der blaugefärbten Milch konnte ich ebenfalls beobachten, sie dauerte etwa 8 Stunden lang. Bemerkenswert ist es, dass es trotzdem zu einer diagnostisch ausreichenden Füllung der Gallenblase kam. Die Aufnahmen zeigten einen verhältnissmässig kontrastarmen Gallenblasenschatten von normaler Grösse mit zahlreichen runden Aufhellungen (Konkremente).

Die Behauptung älterer Verfasser, wonach »das Kontrastmittel nicht in die Brustmilch übergeht» (Eisler u. Nyiri) kann daher nicht mehr aufrechterhalten werden. Sie ist durch die Fälle des Herrn Olsson, wie auch durch meine obige Beobachtung einwandfrei widerlegt.

FROM THE RADIOPHYSICAL INSTITUTION (CHIEF: PROF. R. SIEVERT), THE ROENTGEN-DIAGNOSTIC DEPARTMENT (CHIEF: PROF. Å. ÅKERLUND), AND THE MEDICOPHYSIOLOGICAL CENTRAL LABORATORY, MEDICAL CLINIC I (CHIEF: PROF. N. SVARTZ), OF KAROLINSKA SJUKHUSET, STOCKHOLM.

ON THE POSSIBILITY OF STUDYING THE FUNCTION OF THE HEART WITH THE AID OF ROENTGEN-CINEMATOGRAPHY[1]

Roentgen-Cinematography Combined with Electric Recordings of the Resistance of the Cardiac Valves

by

Sven Benner, Sven Roland Kjellberg and *Torgny Sjöstrand*

In the past few years roentgen-cinematography has been made use of in an endeavour to obtain increased knowledge of the function of the heart and the passage of the blood through the heart under conditions as physiological as possible. The first to employ this method for such investigations seems to have been BÖHME, who in 1936 published his researches on dogs and cats. The technique has subsequently been used by JANKER, PIETRUSKY and WESTERMARK. Generally these investigations have confirmed and elucidated earlier results obtained with other methods. In his recently published investigations, however, WESTERMARK has arrived at a very remarkable conception of the function of the heart, entirely different from the one generally adopted by physiologists. WESTERMARK thus considers that he has been able to establish that the mitral and tricuspid valves of the rabbit do not open immediately after the relaxation of the ventricles — at the end of T in the electrocardiogram — but later, during the contraction of the auricles — thus at the beginning of P in the electrocardiogram. According to WESTERMARK the semilunar valves do not open at the beginning of the systole but only at the middle of that phase and at a time represented by the beginning of the T wave in the electrocardiogram.

Due to the difficulty in bringing WESTERMARK's results into accord with the results obtained with other methods, an examination has now

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been made of the method and its sources of error. In doing this, special attention has been given to a comparison between the exact time for the opening and closing of the valves and the first flow of contrast medium into the ventricles as demonstrated in the roentgen film. For this purpose a technique has been used which considerably enhances the possibilities of studying the function of the heart as recorded by roentgen-cinematography.

Method

In order to establish the exact point of time when the valves open and close in the roentgen film the electric resistance between ventricle and auricle was simultaneously recorded. The valves in the rabbit's heart have an interior frame of connective tissue, on both sides surrounded by epithelium, the endocardium. Owing to their structure they have a fairly considerable electric resistance in spite of their thinness. Measurements made on atrio-ventricular valves removed from rabbits disclosed that this resistance amounts to approx. 8,000 ohms. Due to this great resistance even small changes in the position of the valves produce alterations in the resistance between two electrodes on either side of the valves.

The variations in the electric resistance were recorded as follows: A so-called concentric needle-electrode was inserted into each of the two chambers of the same half of the heart, the outer electrode being connected with an A. C. generator and the inner electrode with a recording device, *cf.* wiring-diagram fig. 1. The voltage as well as the frequency of the current could be regulated within a wide range. The current most suitable for the measurements was about 0.5 mA and had a frequency of 1,000 cycles per sec. An amplifier with oscillograph (Electrical Fono-Film) was used as a recording apparatus and the circuit was supplied with a filter which only allowed the passage of frequencies exceeding 500 cycles per sec. On account of the fairly high frequency of the current used for the measurements of the resistance, the curve — when the speed of the paper on which it was traced was not too great — obtained the appearance of a heavy line the width of which varied with the resistance in the circuit. When the resistance increased the width of the line likewise increased, and when the resistance decreased the line became thinner.

In order to be able directly to compare the recording of the resistance with the film taken simultaneously, the camera was supplied with a contact-device which at each exposure closed the circuit to an oscillograph. In this way each exposure was recorded on the same paper as the resistance curve. To obtain an exact correlation between the two recordings two signals were also designed to make simultaneous marks

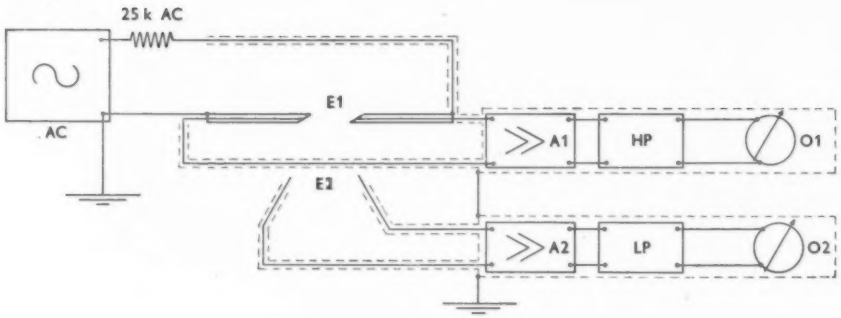

Fig. 1. *Wiring-diagram.*

AC A. C. generator
E1 electrodes for recording the resistance
A1 amplifiers for recording the resistance
HP high passage filter designed to prevent the electrocardiogram current from reaching O1
O1 oscillograph for recording the resistance
E2 electrocardiogram electrodes
A2 electrocardiogram amplifiers
LP low passage filter designed to prevent the current for the measurement of the resistance from reaching O2
O2 electrocardiogram oscillograph

on the film and the oscillogram. On the latter were also recorded the electrocardiogram of the animal and the time ($^1/_5$ sec.); see fig. 2. In the circuit to the oscillograph that registered the electrocardiogram of the animal there was a filter which only allowed the passage of frequencies up to 500 cycles per sec. The two filters mentioned prevented the electrocardiogram from influencing the resistance curve and the current for the measurement of the resistance from influencing the electrocardiogram.

In these experiments rabbits were used exclusively; they were anaesthetized with pernocton and were administered artificial respiration. After the anterior chest wall had been removed and the pericardial cavity opened, the electrodes were inserted in the respective chambers. The needles were inserted in such a way that their points were directed from either side towards the ostium whose valves were to be examined. The needles were fastened in two holders and their position was controlled by fluoroscopy.

The contrast medium used was thorotrast, it being the only opaque medium available combining contrast density with but slight irritation of heart and vessels. It was injected intravenously into the right jugular vein. In order to obtain the same electrical resistance in the thorotrast

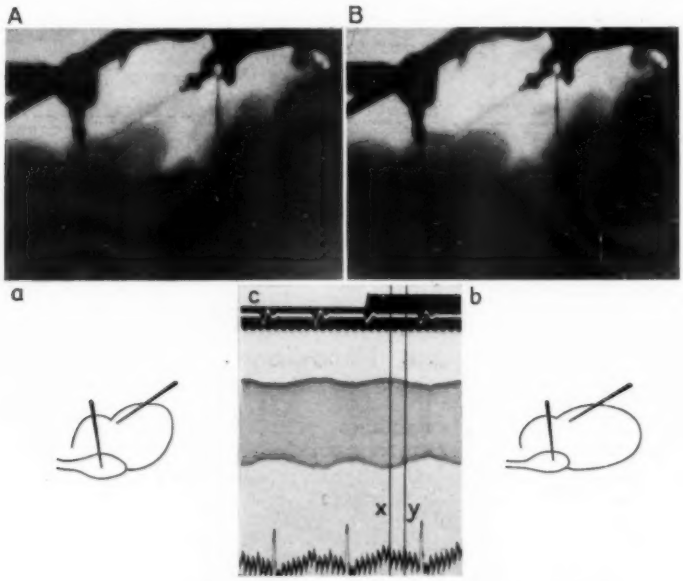

Fig. 2. A and a: Roentgen picture and elucidatory outline-drawing of a rabbit's heart towards the end of the systole, corresponding to X in C. The electrodes for recording the resistance are seen inserted into the right auricle and ventricle.

B and b: Ditto from the beginning of the diastole, corresponding to Y in C. $^{2}/_{10}$ sec. after A. No contrast definitely demonstrable in the ventricles, although the change in the volume of the ventricles and the auricles indicates that blood has penetrated from the auricle into the ventricle.

C: Electrocardiogram, oscillogram of the resistance between the right auricle and ventricle, exposure signal and time signal, all obtained simultaneously with the roentgen film. At X, just after the maximum of the T wave, the resistance is great. At Y, $^{2}/_{10}$ sec. after X and at the beginning of the P wave, the resistance has already decreased considerably, indicating that the tricuspid valves were opened still earlier.

Time of exposure $^{1}/_{5}$ sec.

solution as in the blood, the thorotrast was first mixed vith a predetermined quantity of saline solution with a concentration corresponding to 10 times that of ordinary Ringer's solution. The film pictures were analysed after being projected and after the outline of the heart being copied on an enlarged scale.

The film camera was worked at the rate of 32 pictures per second.

Results

The simultaneous recording of the electrocardiogram and the electric resistance between the right auricle and ventricle shows that the resistance

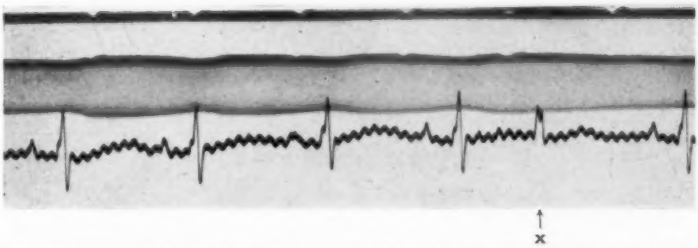

Fig. 3. Record of the resistance between the right auricle and ventricle together with the electrocardiogram for a low heart rate. The electric resistance between auricle and ventricle decreases immediately after T and before the P wave. At x an extra systole during which the resistance remains unchanged until the middle of the T wave, incomplete contraction.
Time of exposure $^1/_8$ sec.

is greatest during the systole and least during the diastole. As is apparent from fig. 2, there is a fairly rapid decrease in the electric resistance at the end of the T wave. When the heart frequency is high, *i. e.* when the P wave begins just after the T wave of the preceding cardiac period, the reduction in the resistance is seemingly in relation to the P wave. The heart rate being slower, and the distance between T and P increasing, *e. g.* after an intravenous injection of acetylcholine, the decrease in the resistance is, however, still found to begin at the same time in relation to the T wave but considerably earlier than the P wave. This proves that the moment for the beginning of the reduction in the resistance is independent of the heart rate and of the P wave of the subsequent cardiac period, see fig. 3. The fairly sudden reduction in the resistance (see fig. 2 c) thus sets in at a time, when according to current opinion hitherto, the mitral and tricuspid valves open, which thus must explain the reduction. The resistance is practically unchanged throughout the middle part of the diastole but is then decreased during the P—Q interval. At the end of the initial complex, corresponding to the S wave, the resistance increases, first fairly rapidly and then more slowly, and reaches its maximum at the middle or in the second half of the T wave. This is seen in figs. 2 and 3. This increase in the resistance is explained by the fact that the tricuspid valves close at S and the ventricle is drained of blood during the systole. The quantity of blood between the electrode in the ventricle and the valves thus gradually decreases, which must increase the electric resistance between the two electrodes.

If, on the other hand, the electrodes are placed in the right ventricle and the pulmonary artery or in the left ventricle and the aorta respectively, the resistance oscillograms portray conditions which are practically the reverse of those shown by the oscillograms for the right auricle and

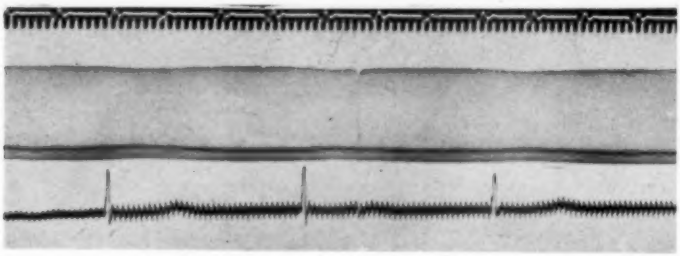

Fig. 4. Oscillogram of the resistance between the right ventricle and the pulmonary artery together with electrocardiogram and exposure signals. The electric resistance decreases during the first half of the systole and then increases slowly. During the diastole the resistance is unchanged.
Time of exposure $^1/_5$ sec.

ventricle. As is seen from fig. 4, the resistance decreases fairly suddenly at a point of time corresponding to the end of the initial complex in the electrocardiogram and increases at the end of the T wave.

A simultaneous analysis of the resistance oscillograms from the right auricle and ventricle, the electrocardiogram and the roentgen film of the passage of the contrast medium through the heart discloses that *no contrast medium can be demonstrated in the ventricle at the time when the resistance begins to decrease after the end of the T wave. Not until three exposures later can thorotrast definitely be demonstrated in the ventricles.* The camera being worked at the rate used by us (32 pictures per sec.), 3 exposures take about $^1/_{10}$ sec. One of us (KJELLBERG 1943) has studied the passage of a blue thorotrast solution through a glass model of a heart. A colour film and a roentgen film were taken, and upon comparing the two it was found that the entrance of the contrast medium into the ventricle could be observed about one-tenth of a second earlier in the colour film than in the roentgen film. The explanation is that the roentgen film is less sensitive to small changes in the opacity than the colour film is to small variations in the shades of colour.

When analysing the outline of the heart in the roentgen film it is fairly easy to determine the beginning of the systolic phase and the setting in of the diastolic phase (fig. 2 A and B). The contraction begins one exposure before the change in the resistance and is most clearly evident towards the apex. In the same way it can be ascertained that the relaxation occurs simultaneously with or immediately before the reduction in the resistance between the auricle and ventricle as demonstrated by the oscillogram. When the rate of circulation through the heart is slow, it is also easy to observe in the roentgen film that the volume of the ventricle increases before the contraction of the auricle sets in.

Discussion

The recording of the resistance between the auricle and the ventricle and between the ventricles and the pulmonary artery and the aorta respectively has thus shown that the moments for the opening and closing of the various valves as established in that manner are in good agreement with the general conception of physiologists, based on other methods. On the other hand it does not seem possible to draw any conclusions regarding the opening and closure of the valves on the basis of the passage of the contrast medium as demonstrated in the roentgen film. The contrast medium cannot be shown to have entered the ventricle until about one-tenth of a second after the opening of the valves, which is explained by the fact that the blood must have attained a certain degree of contrast before the contrast medium can be seen. This explains why WESTERMARK has referred the opening and closure of the various valves of the rabbit's heart to a point of time later than the true one.

After enlargement and projection the cinematographic pictures give a good idea of the changes in volume during a heart cycle. At the apex it is furthermore possible to observe the beginning and end of the contraction.

Our investigations demonstrate that the roentgen film method with injection of a contrast medium gives a good picture of the contraction of the heart and of its changes in volume during the systole and the diastole but that it is not suited for a more detailed analysis of the blood flow through the heart. For this purpose the film must be supplemented by other methods, *e. g.* recording of the electric resistance between the various chambers of the heart.

SUMMARY

As roentgen cinematography has been introduced in several quarters for a closer analysis of the functioning of the heart, an experimental investigation has been carried out to determine its possibilities and limitations. With the aid of a contrast medium a study has been made of the circulation through the heart of rabbits, an electrocardiogram and the electric resistance between the right auricle and ventricle, the right ventricle and the pulmonary artery and the left ventricle and the aorta being recorded at the same time. The investigation disclosed that the roentgen film could give an idea of the changes in volume connected with the contractions of auricle and ventricle, but that it is not possible to determine the moment for the opening and closure of the valves with this method. The recordings of the resistance, on the other hand, did yield results in complete agreement with those obtained earlier with the aid of other physiological methods.

ZUSAMMENFASSUNG

Mehrerenorts sind kinematographische Röntgenaufnahmen zur näheren Analyse der Herztätigkeit herangezogen worden. Eine experimentelle Untersuchung wurde vorgenommen, um die Möglichkeiten und die Begrenzung der Methode festzustellen. Mit Hilfe von Kontrastmittel wurde der Kreislauf im Kaninchenherzen studiert und gleichzeitig ein Elektrokardiogramm aufgenommen sowie der elektrische Widerstand zwischen rechtem Herzohr und rechter Kammer, rechter Kammer und Lungenschlagader, linker Kammer und Aorta gemessen. Die Untersuchung ergab, dass der Röntgenfilm ein Bild von den Volumenveränderungen bei der Kontraktion von Herzohr und Kammer geben kann, dass es jedoch nicht möglich ist, mit dieser Methode den Augenblick der Öffnung und Schliessung der Klappen festzustellen. Die Messung des Widerstandes ihrerseits gab Resultate, die völlig mit den früher mit Hilfe anderer physiologischer Methoden erzielten übereinstimmten.

RÉSUMÉ

La Roentgencinématographie ayant été introduite de divers côtés pour analyser de plus près le fonctionnement du cœur, les auteurs ont fait des recherches expérimentales pour déterminer ses possibilités et ses limites. A l'aide d'une substance opacifiante ils ont étudié la circulation dans le cœur de lapins en même temps qu'ils prenaient un électrocardiogramme et enregistraient la résistance électrique entre l'oreillette et le ventricule droits, le ventricule droit et l'artère pulmonaire, le ventricule gauche et l'aorte. L'étude révèle que le film Roentgen peut donner une idée des changements de volume correspondants aux contractions de l'oreillette et du ventricule, mais qu'il n'est pas possible de déterminer par cette méthode le moment d'ouverture et de fermeture des valvules. D'autre part l'enregistrement de la résistance a fourni des résultats qui s'accordent parfaitement avec ceux obtenus antérieurement à l'aide d'autres méthodes physiologiques.

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FROM THE ROENTGEN CLINIC OF THE MUNICIPAL HOSPITAL, AARHUS, DENMARK AND THE RADIUM CENTRE FOR JUTLAND
(CHIEF: PROFESSOR CARL KREBS, M. D.)

DETERMINATION OF THE DOSE IN CIRCULAR PHANTOMS UNDER ROTATORY IRRADIATION[1]

by

Howard Nielsen

In the course of time many different attempts have been made to approach the purpose of deep roentgen therapy, which must be to concentrate the greatest possible roentgen dose in the depth, with the least strain on the overlying tissues. One of the finest solutions of this problem is found in the rotatory irradiation. The principle of this, is to center the rays against the lesion while rotating the body (or target) with a line through the lesion as rotatory axis.

The particular distribution of the dose arising in a body exposed to rotatory irradiation has already been the subject of previous measuring as well as mathematical treatment. As these problems cannot be said yet to have been settled conclusively, the writer has tried in the studies to be reported here, to clear up this question through measuring on phantoms under the most simple and easily surveyable conditions, so that the result should be most easily comparable to the calculations.

In rotatory irradiation the favorable proportion between the surface dose and the depth dose is due to the fact that each point in the irradiated body lying outside the axis field is exposed to radiation only while passing through the cone of rays, *i. e.*, twice during a rotation of 360°, whereas all points situated within the field of the axis are irradiated continually. To what extent the favorable effect is dependent on the size of the field, the thickness of the phantom, the quality of the rays and the target-skin-distance, is not surveyable offhand, as several of the features mentioned are antagonistic.

These studies cover the amount of the surface dose (S) and the dose in the center of the rotation — the axis dose, or center dose (C) — at

[1] The present work was carried out with the aid of a grant from Kong Christian X's Fond, submitted for publication March 24, 1944.

a given »output» (Einfallsdosis), and the dependency of these values on the diameter of the phantom, size of the field, radiation quality and divergence of rays (target-center distance) and, finally, the dependency of the dosage distribution in the phantom upon the conditions mentioned. For the calculations of the depth dose we have no fixed surface field for starting point as on irradiation through fixed ports, hence it has to be expressed by means of the values known, namely: the output, phantom diameter and axis field (*i. e.* the diameter of the field perpendicular to the rotatory axis). At all distances from the target this can be calculated from the size of the diaphragm and from the distance between the target and the diaphragm.

Experimental Procedure

The phantom was rotated regularly by means of an electrical phonograph motor in front of the source of the rays. The target-diaphragm distance was 20 cm., and when nothing else is mentioned the distance from the target to the center of rotation was 50 cm. The measurings were performed in cylindrical paraffin phantoms, 20 cm. in height and 15—20—30 cm. in diameter; holes for the points of measurement were drilled from the end surface, at a depth of 10 cm. and situated in a spiral round the center. After the measuring chamber was placed, the rest of the hole was filled with a plug of paraffin. The source of the rays was a therapeutic tube, Philip's Super T, with grid-controlled tube (Villard coupling pulsating direct current). The tube has been employed with tensions from 125 kV max. to 175 kV max. and has been extraordinarily constant in its yield of rays, which during the experiment was measured daily with Küstner's Eichstandsgerät and converted to output (O) (= dose measured at a distance of 50 cm. in air). No regard was paid to the absorption in the air. Comparison of the results obtained by employment of the mentioned apparatus and another therapeutic tube, Radio Constant, Koch u. Stertzel, likewise equipped with Philips grid-controlled tube (Greinacher coupling, direct current) showed no difference.

In order, as far as possible, to obtain a punctate determination of the dose, equalizing irradiation from any side, the measurements were made with an instrument of Sievert's spheric chamber type (1—1) 10 (Acta radiol., Supplement 14, 1932). All the chambers were calibrated in relation to Küstner's Eichstandsgerät at all radiation qualities with HVL from 0.2 to 1.4 mm. Cu. Further they were examined for saturation and proportionality between the radiation time (dose) and loss of potential. These readings were again checked up by control measurements at intervals of four months and showed constancy.

The measuring results are recorded graphically in 3 curves for each phantom (Fig. 1—3). These curves give 1) the dose measured on the surface, recorded in percentage of the output (S/O $\times$ 100), 2) the dose measured in the center, converted to percentage of the output (C/O $\times$ 100) and 3) the proportion between the center dose and the surface dose (C/S $\times$ 100). The last figures thus give the dose in the center relative to a surface dose of 100 r.

The size of the field was varied merely by changing the diameter of the axis field (keeping the heigh constant = 15 cm.).

Surface Dose in Rotatory Irradiation

It is obvious that a wider port gives a longer irradiation time for a point on the surface under 360° rotation: This is evident also from the curves in Fig. 1 which gives the surface dose relative to a value of output = 100 r and differing axis fields. Within certain limits, the surface dose increases proportionally to the diameter of the field — from which it is evident that the illumination time is decisive of the amount of the surface dose. With fixed fields, as is well known, the surface dose increases at first rapidly with increasing field size, reaching a maximum rather soon (at about 150 sq. cm. — according to HOLTHUSEN & BRAUN, l. c. p. 156), a fact which deviates from the findings on rotatory irradiation. Here the increase in the surface dose is not particularly great till the diameter of the axis field approaches the diameter of the phantom.

The dependency of the surface dose on the period in which a point on the surface is passing through the ray cone (illumination time) is also found by increasing the phantom radius with constant axis field (see Fig. 1). In spite of the shorter target-surface-distance (and the greater intensity) a longer phantom radius gives a lower surface dose because of the shorter illumination time.

Also the influence of the radiation quality on the surface dose is evident from the curves. Using as well fixed fields as rotatory irradiation a greater surface dose is obtained by employment of short wave lengths.

Center Dose

As the dose in the center is measured at a point which does not change location under the rotation, the dose will be dependent merely upon the diameter of the axis field, the radiation quality and the thickness of the layer from the center to the surface. Naturally, then, one will expect the dose in the center to comply with the rules for fixed fields. Indeed, the curves in Fig. 2 giving the dose in the center at an output of 100 r, have the same shape as the curve calculated after GREBE & NUTZGE's tables for the center dose with the axis fields employed. The axis dose increases rapidly at first with increasing diameter of the axis field, reaching gradually a maximal value.

Efficiency Coefficient

The term efficiency coefficient (EC) is here adopted for the ratio between the center dose and the surface dose. The curves in Fig. 3—4 illustrate this ratio in rotatory irradiation, and the figures give the dose in

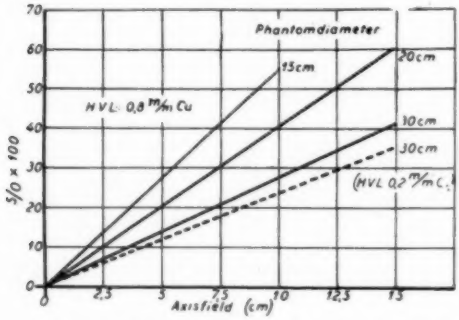

Fig. 1. Relation between surface dose (S) and output (O) ($S/O \times 100$) at different phantom diameters.

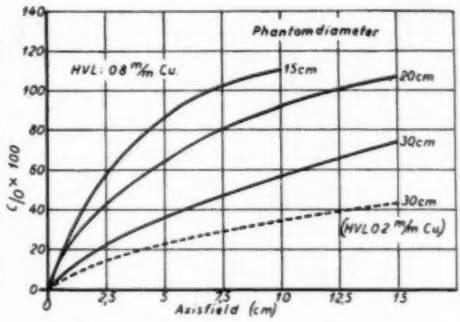

Fig. 2. Relation between axis dose (C) and output (O) ($C/O \times 100$) at different phantom diameters.

the center at a *measured* surface dose of 100 r with different axis fields and phantom diameters.

The dominating influence of the *axis field diameter* on EC is plainly evident from these curves, which show that the efficiency coefficient increases very rapidly with narrowing of the field. As the axis dose decreases with decreasing field diameter (Fig. 2) the rise in EC may be due to a more rapid fall in the surface dose than in the center dose. Increasing the field diameter the efficiency coefficient decreases rather rapidly — in contrast to the results in fixed fields (HOLTHUSEN, *l. c.*, p. 162). Under particular conditions EC may arise to values over 600 %, but even with the largest field and at a depth of 15 cm. (Fig. 4) an efficiency coefficient of 150—180 % will be obtained, that is, at any rate more than three times the effect obtainable under the most favorable conditions by irradiation through one fixed field.

The influence of the *radiation quality* on the efficiency coefficient is likewise evident from the curves Fig. 4: it is greatest using hard rays. It is further seen that no essential improvement of EC is obtained by increasing the hardness of the radiation from HVL 0.8 mm. Cu to HVL 1.4 mm Cu. The significance of the absorbing layer — the *phantom radius* — to the efficiency coefficient, is evident from comparison of the values for the same axis field in the three phantoms. Thus the efficiency coefficient is seen to increase from 300 % to 350 % with increasing radius, in spite of the increase in the absorbing layer (Fig. 3, for instance, axis field of 5 cm.) After this, the efficiency coefficient decreases with increasing radius from 350 % to 270 %. The efficiency coefficient not being greatest in the smallest phantom, is due to the fact, that in this phantom the surface is exposed to more intense irradiation while it passes through the

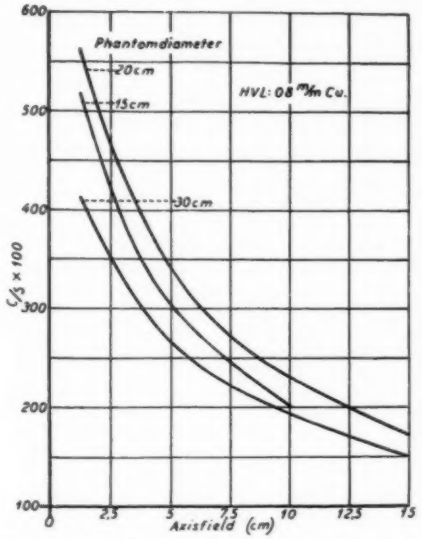

Fig. 3. Relation between axis dose (C) and surface dose (S) (C/S × 100) at different phantom diameters.

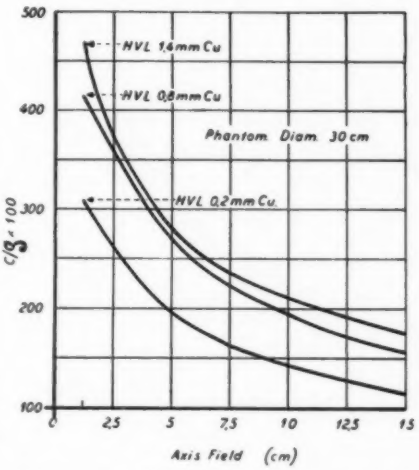

Fig. 4. Relation between axis dose (C) and surface dose (S) /C/S × 100) at different radiation qualities.

»exit cone» (*i. e.*, the surface turning away from the tube) owing to the slight thickness of the layer.

With a phantom diameter of 20 cm. the ratio of deep to surface dose is most favorable.

Under irradiation through fixed fields a noticeable increase in the deep-to-surface ratio is observed with a large target-surface distance, owing to the balance of the ray divergence. Experiments show that with rotatory irradiation the efficiency coefficient may be about 30 % greater at a target-center distance of 80 cm. than at a target-center distance of 30 cm.

The curves show that using rotatory irradiation the most favorable radiation conditions are obtained with narrow axis fields, medium-sized phantom radius, hard rays and great target-center distance. In practice, the radius (cross-section of the body) is given and the axis field is determined by the extension of the tumor, so that changes in the conditions are limited to the target-center distance and the radiation quality. Increase in the distance implies rather heavy expenses (long irradiation time) and as an increase in the hardness of the radiation beyond HVL of 0.8 mm. Cu, as demonstrated, offers no advantage worth mention, it will be most profitable to employ a radiation of this quality. In this way, in practice, we may obtain a depth effect of about 3 times the skin dose.

Distribution of the Dosage

In the planning of deep irradiation it is of the greatest importance to know the dose at all points between the surface and the lesion — the spatial dose distribution. With fixed fields this dose distribution will depend on the radiation quality, field size and intersection of the ray cones. In rotatory irradiation the dose at a given point, situated between the axis field and the surface, will depend on the diameter of the ray cone (illumination time), whether the point is situated near the surface (shorter irradiation time and a lesser absorption in the overlying layer) or near the axis field. Points in the immediate vicinity of the axis field will receive a larger dose, as they have to pass through the scattered irradiation round the ray cone. How the dose distribution is dependent on the phantom radius, the ray quality and the axis field is easily seen from the curves. (Fig. 5.) The dose in the center is set at 100 %, and the doses at all other points are converted in proportion hereto. The uncertainty involved in the determinations for the individual points is about 1—2 %.

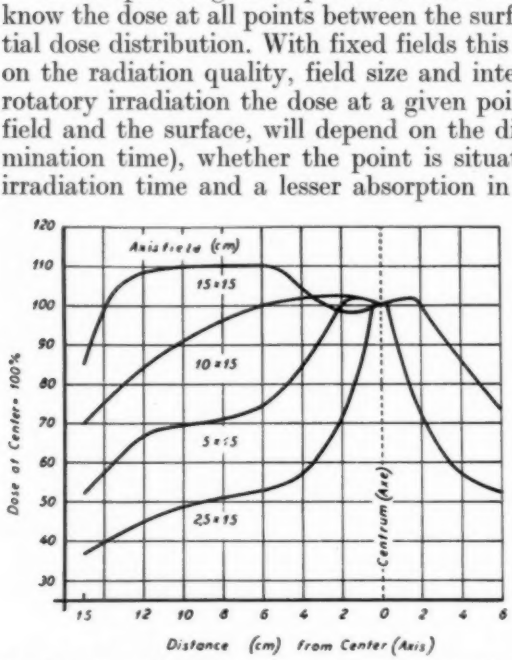

Fig. 5. Dose distribution curves for different axis fields in the same phantom (diameter 30 cm) HVL = 0.2 mm Cu.

The width of the ray cone (the axis field) has a predominant influence on the appearance of the dose curve. Fig. 5 thus presents the dose distribution curves in a phantom with a diameter of 30 cm. for axis field diameters of 2.5, 5, 10 and 15 cm. The lowest curve (axis field 2.5 cm.) shows an abrupt fall in the dose round the border of the axis field, and ca. 4 cm. from the center the dose has decreased to about 55 %, wherefrom the dose falls slowly towards the surface — with plateau formation. With a broader ray cone (axis field 5 cm.) the fall of the dose is less abrupt outside the axis field, and at a distance of about 5 cm. from the center the dose reaches values of about 75 %, whereafter it falls gradually towards the surface. With wider axis fields the fall of the dose between the axis field and its surroundings is more gradual, and the curve may even form plateau outside the axis field with values 10 % higher than the axis dose

(Fig. 3, axis field 15 cm.), in which case the maximum dose forms a cylindrical coat round the axis. There is never any rise in the dose just beneath the surface — such as is seen on employment of fixed fields.

The form of the distribution curve is not decided exclusively by the diameter of the axis field. In the small phantoms the curve falls abruptly outside the axis field; the greater the phantom radius, the more pronounced is the plateau formation, the curve lying at a higher level.

The radiation quality has a not inconsiderable influence on the distribution curve. Within the axis field the form of the curve is nearly the same whether the rays are hard or soft (a little lower for hard rays), but outside the axis field the curve falls more abruptly with employment of hard rays (less pronounced plateau formations, smaller volume dose).

With the hard rays no values higher than the axis dose are seen outside the border of the field — such as observed, for instance, in the top curve in Fig. 5. A curve obtained and plotted under the same conditions (axis field 15 cm.) as the last-mentioned but for radiation with HVL of 1.4 mm. Cu. will be congruous with the curve shown in Fig. 5 for axis field 10 cm.

The ideal distribution curve, with a fall of the axis dose to the »skin dose» immediately outside the axis field, is not obtained in any instance, but the outcome of these considerations is: that the most favorable dose distribution (smallest volume dose) is obtained with narrow axis fields, a small phantom radius and hard rays. If a homogeneous irradiation of extensive deep lesions is desired, however, rotatory irradiation will be highly suitable too: no intersection of the fields on or beneath the skin, no »dead zones», and a well-defined homogeneous dose throughout the field.

Discussion

In 1913 HANS MEYER as the first advanced the idea of letting many small fixed fields be replaced by one wandering field. He gave a theoretical basis for the advantages offered by this procedure, and he established it gives a uniform dose distribution in the depth — a better »Dosenquotient».

The rapid development of the high tension technique after the war made rotatory irradiation less topical, however, as improvement of the depth effect was obtained with high tension apparatus and better tube types. So the idea of rotatory irradiation did not turn up anew till 1929 (ARCHANGELSKI), 1937 (DESSAUER, FLAX), 1938 (HENSCHKE) and 1939 (KOHLER).

Common to most of the works dealing with rotation therapy is the fact that the information given about the measuring technique and ad-

justment of the measuring instruments is defective, making comparison of the results very difficult.

Of significant works dealing with the problems of rotatory irradiation, particular mention is to be made of four recent ones. In five publications RENÉ DU MESNIL DE ROCHEMONT (1937—41) has given a very thorough theoretical and mathematical account of the dose aspects; and in an excellent paper NAKAIDZUMI & MIAYKAWA (1939) have presented their measuring results. HAWLEY (1940) has measured the surface and axis doses in phantoms of pressed wood, formed as a pelvis, together with the intensity distribution. Finally, JENS NIELSEN (1941) — who as the first in Scandinavian countries introduced the employment of rotatory irradiation in the therapy — has published a report on the therapeutic technique, accompanied by measurements on an oval wax phantom with air spaces (corresponding to the lungs).

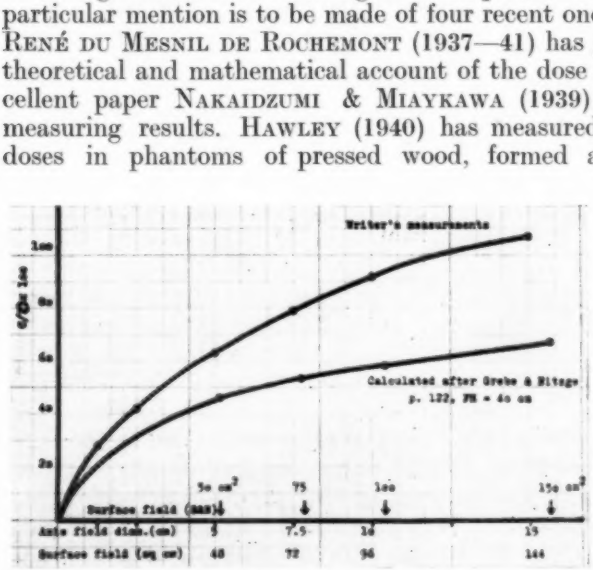

Fig. 6. Comparison between calculation (Grebe & Nitzge) and the writer's measurements for depth dose at a depth of 10 cm. (radius = 10 cm.). HVL: 0.80 mm Cu.

As the two last-mentioned works deal with conditions not considered in the present studies, no further mention will be made of them here. It may be added, however, that the results reported by these authors appear to agree with the findings obtained by the writer in experiments on similar phantoms now going on.

In the following a comparison will be made merely of measurements (by NAKAIDZUMI and by the writer) with calculations presented by MESNIL DE ROCHEMONT. In these calculations, however, no regard was paid to the ray divergence or the influence of secondary radiation, and it was necessary to extrapolate from HOLTHUSEN's intensity curves.

According to DE ROCHEMONT, the *surface dose* changes precisely with the illumination time for a point on the surface, which agrees very well with my own findings (Fig. 1). DE ROCHEMONT calculated the *axis dose* from the size of the field and the phantom radius, after GREBE & NITZGE's tables. In the present studies such a calculation has been performed for the field sizes employed in my experiment (Fig. 6), from which it will be

noticed that the measured values are considerably higher than those calculated after GREBE & NITZGE. The reason for this deviation is to be looked for chiefly in the different measuring technique on which the plotting of the two curves was based. Apparently the figures given by GREBE & NITZGE are based chiefly on measurements in water phantom with »fingerstall» chambers. Employment of SIEVERT's chambers gives a better registration of the radiation as they are smaller (10 mm. against ca. 20 mm.); further, they are entirely surrounded by the medium in which the dose is measured, receiving thus radiation from all sides.

DE ROCHEMONT has also investigated the *efficiency coefficient* with different ray qualities and found that hard rays give a high efficiency coefficient (»kleinem Absorptionsverlust, grossem Streuzusats») which is in harmony with the findings obtained by NAKAIDZUMI and by the writer. As to the influence of the phantom radius on the efficiency coefficient, DE ROCHEMONT arrived at the following conclusion: »Wir erhalten also im allgemeinen mit abnehmendem Körperduchmesser eine Verbesserung der Tiefenwirkung. Allerdings (kan) bei sehr kleinen Radius — bei relativ zum Körperdurchmesser sehr breiten Strahlenkegel — wird die Tiefenwirkung wieder geringer». Also this agrees with the values measured by the writer (not examined by NAKAIDZUMI). In keeping with the observations reported by NAKAIDZUMI and the values presented in the present Fig. 3—4, DE ROCHEMONT found narrow fields to give a higher efficiency coefficient, which he explains in this way: even though a higher efficiency cofficient may be expected both with large fields (grossem Streuzusats) and with narrow fields (grossem Belichtungszeitunterschied) the latter factor will be decisive.

On the other hand, no agreement is found between DE ROCHEMONT's calculations and the writer's observations as to the significance of the target-surface distance to the efficiency coefficient. From the curves presented by DE ROCHEMONT it is evident that with the same axis field the efficiency coefficient increases with decreasing target-surface distance. He says: »Ein günstiges Verhältnis der Herddosis zur Oberflächendosis erhält man bei starkem Breitenunterschied zwischen Hautfield und Herd (die grenze des dauernd im Strahlenbereich bleibenden Kerngebiets rückt dann naher an die Oberfläche) also kleinem Focus-Haut-abstand». It is to be kept in mind, however, that with a short target-surface distance the exit cone is wider and the illumination time for a point passing through this cone is longer. In contrast to DE ROCHEMONT's calculations, the values obtained by the writer — which agree with the findings reported by HAWLEY — show the efficiency coefficient to be about 30 % greater with a target-center distance of 80 cm. than with a target-center-distance of 30 cm.

The *dosage distribution curves* calculated by DE ROCHEMONT show several deviations from the measured ones. (NAKAIDZUMI plotted curves for 3 field diameters in a circular phantom with a diameter of 20 cm.; and, point by point these curves are congruous with those obtained by the writer.) The *calculated* dosage distribution curve falls abruptly from the margin of the axis field towards the surface, reaching the surface-dose almost immediately. This deviation from the measured curves (Fig. 5) is due to the secondary radiation. A more or less wide coat of scattered radiation round the axis field will flatten the distribution curve and balance the difference between the axis region and peripheral region. This applies in particular to the broad fields which give a greater amount of secondary radiation.

The apex of the *calculated* dosage distribution curve lies at a higher level than the apex of the measured curve (at about 580 % for the calculated curve and about 340 % for the measured). Comparing his own calculation with NAKAIDZUMI's figures, DE ROCHEMONT explains this difference as attributable to the circumstance that the depth dosage curve employed by him has given a too high percental depth value, and that he had to interpolate on HOLTHUSEN's curves, making thus the values inaccurate — especially for the surface dose.

It is practicable to calculate the dose distribution in rotatory irradiation of circular homogeneous bodies without making use of phantom measurements. This may be carried out, for instance, by means of the formular for the weakening of roentgen-rays in solid substance ($I = I_0 e^{-\mu d}$), when no regard is paid to divergence or secondary radiation. But such calculations are impracticable when the question is of heterogeneous bodies with a non-uniformly curved surface as will practically always be the case on cross-section of the human body. So we have to make use of phantom (and cadaver) measurements if these more complicated questions are to be elucidated — and studies of this kind will be reported subsequently.

The theory concerning rotatory irradiation, the measurements and the therapeutic results reported already (JENS NIELSEN, NAKAIDZUMI) make it reasonable to assume that the rotatory irradiation will be of more than temporary interest if the dosage may be simplified to the same extent as the dosage in ordinary roentgen treatment. But, of course, until a reliable base for the depth dose has been obtained by measurements or calculations, the clinician has to be cautious in the employment of the rotatory irradiation, as the risk of overdosage here is far greater than in ordinary roentgen treatment. The usually unaffected general condition of the patient, and the slight skin reaction under rotatory irradiation will not warn the therapeutist in time.

SUMMARY

After an account of the measuring technique and results obtained by measuring of the dose in cylindrical phantoms under rotatory irradiation, it is shown how the dose on the surface and in the center together with the dose distribution vary with changes in the field size, radiation quality, phantom radius and target-center distance.

The results are presented in form of curves which allow the reading of the dose in the center and on the surface with a given output and a given axis field diameter. In this way an approximate picture of the conditions in a cross section of the body may be obtained.

The values measured for the dose in the center are considerably higher than the calculated, and the difference between the measured and the calculated dose distribution curve is mentioned. The reasons for these differences are discussed.

ZUSAMMENFASSUNG

Nach einem Bericht über die Messungstechnik und die beim Messen der Dosis in zylindrischen Phantomen bei Rotationsbestrahlung gefundenen Ergebnisse, wird nachgewiesen, wie die Dosis an der Oberfläche und im Inneren sowie die Verteilung der Dosen mit Veränderungen der Grösse des Feldes, der Art der Strahlung, des Durchmessers des Phantoms und des Brennpunktabstandes wechseln.

Die Ergebnisse werden in Form von Kurven vorgelegt, die ein Ablesen der Dosis im Inneren und an der Oberfläche bei gegebener Strahlenmenge und gegebenem Achsenfelddiameter erlauben. In dieser Weise lässt sich ein approximatives Bild der Verhältnisse in einem Querschnitt durch den Körper erhalten.

Die gemessenen Werte der Dosis im Inneren sind bedeutend höher als die berechneten. Es wird der Unterschied zwischen der gemessenen und der errechneten Dosenverteilungskurve erwähnt. Die Ursachen dieser Unterschiede werden besprochen.

RÉSUMÉ

Après un rapport sur la technique de mensuration et les résultats obtenus en mesurant la dose sur des mannequins cylindriques pendant l'irradiation rotatoire, l'auteur décrit comment la dose au centre et à la surface, ainsi que la répartition des doses, varient avec les changements de la dimension du champs, la qualité de l'irradiation, le rayon du mannequin et la distance targe — centre.

Les résultats sont présentés en forme de graphiques, qui permettent la lecture de la dose au centre et à la surface avec une quantité d'irradiation donnée et un diamètre donné du champ axial. De cette manière on reçoit une image approximative des conditions dans une intersection du corps.

Les valeurs mesurés de la dose du centre sont considérablement plus hautes que celles calculées, et la différence mesurée et calculée entre la répartition des doses est donnée. Discussion des raisons de ces différences.

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(HEAD: PROF. Å. ÅKERLUND)

PROTRUSIONS OF DISKS AND NERVE COMPRESSION IN THE LUMBAR REGION[1]

by

K. Lindblom

Two years ago the author of the present paper published a report on the results of an anatomic study of protrusions of disks through the intervertebral foramina of the lumbar vertebrae. The following pararaph summarizes the conclusions reached.

Dorsolateral protrusions of disks at the intervertebral foramina are often observed in anatomic specimens, and these are largely combined with compression of the nerves and ganglia on a line with the outer part of the foramina at the point where the nerve pierces the disk. At a lecture read before a meeting of the Swedish Societies for Internal Medicine and Medical Radiology, in December 1941, the writer expressed the opinion that these nerve compressions are so common that no further explanation need be sought to account for the symptoms occurring in the large majority of sciatica cases; in other words, »Sciatica means the rupture of a disk».

This thesis aroused opposition, however, and severe criticism was directed from many quarters against the interpretation placed on the anatomic findings and the absence of clinical information with regard to sciatic pain in most of the cases reported. The writer has therefore extended his studies, and the present communication offers an account of both the earlier results and those obtained from the later investigation.

The previous literature on the subject is almost exclusively concerned with protrusions and ruptures of disks into the vertebral canal, whereas herniated disks with a more lateral location, causing compression of the nerves, such as those described by the writer, have not earlier received attention or been attributed much clinical significance. The Anglo-American literature of the past two years has not been available for study, however. Of the publications from other countries, mention may be made

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of a paper by HAGLUND (1942), in which similar lesions in the cervical region are reported. He demonstrated that the so-called arthroses in the unco-vertebral joints are in reality disk degenerations, with fissures running from the central parts out towards the intervertebral foramina, and accompanied with local protrusion in this segment resulting in compression of the nerves and vessels. In one case described both by JONSSON and HAGLUND there were clinical symptoms in the vicinity of the fourth rib, and at autopsy the nerve involved was found to be compressed because of a disk protruding into the intervertebral foramen.

Several other authors mention the intervertebral foramen in connection with their findings, but as a rule the part in question is that adjoining the vertebral canal. According to the surgical literature, it is not the root in the same segment but that in the following one which is compressed through the outward bulging of a disk. MALMROS (1942) diverged slightly from this statement, admitting that a lateral prolapse may also cause compression of the root in the same segment but pointing out that this must surely be a rare occurrence in the foramina of the four upper lumbar vertebrae, in which the nerve pursues an oblique course, and in which there is plenty of space to spare. FRIBERG (1941) mentioned in connection with a study of anatomic specimens that he had found the nerve in the same segment to be to some extent attached to the disk, but he observed no compression of the nerves in this area. BROCHER (1938) says: »Auf der Höhe von pathologisch schwer degenerierten und erniedrigten Zwischenwirbelscheiben haben wir mehrmals das Foramen interspinosum mitsamt dem darin liegenden Nerven untersucht. Trotz der Erniederung liegt der Nerv noch allseits wohl umgeben in einem Fettkissen». He considered, therefore, that nerve compression in this part of the spine must be unusual. WILLIAMS (1937) thought that narrowing of the intervertebral foramina, if sufficiently pronounced, could cause sciatica, but he apparently laid chief stress on the part played by the intervertebral joints in producing this condition. HADLEY (1939) and RAAF (1941) mentioned encroachment of the intervertebral foramen associated with a fibrosis about the nerve-root bundles, giving rise to symptoms of radiculitis. They supplied no details with regard to the nature and location of the lesions, however. Judging by the word »nerve-root» it would almost seem as if, in this case also, the statements refer to the medial part of the foramina.

In the literature dealing with spondylitis deformans several authors mention observations indicating a connection between this disease and lumbago and sciatica. Among these are BÁRSONY, GUNTHER and KERR, KIENBÖCK, LYON and LASSILA. They adduce no anatomic features likely to explain the sciatic pain, however.

Valuable contributions to the anatomic aspect of the problem are provided by papers on the innervation of the disks, by SAPPEY, HOVE-

LAQUE, JUNG and BRUNSCHWIG, and ROOFE. Recurrent nerves feed the ligaments of the vertebral bodies, and ROOFE also noted nerve threads in the annulus fibrosus. Thus, the assumption that all changes in the intervertebral fibrocartilage take place absolutely painlessly (GÜNTZ) can no longer be regarded as tenable.

The ligamenta flava and the intervertebral joints have also been brought into the picture in the speculations regarding the cause of lumbago and sciatica. According to observations made during operations, first by ELSBERG in 1913, and later by SPURLING, MAYFIELD and ROGERS, BROWN, BRADFORD and SPURLING, LOVE, and others, thickening of the ligamenta flava is occasionally present, and can cause compression of the nerve-roots from behind. The results of anatomic studies by, among other investigators, TOWNE and REICHERT, and NAFFZIGER, INMAN, and SAUNDERS seem to confirm these operative findings. The possibility that compression might result from arthritic changes in the intervertebral joints has been suggested by several authors, such as FRIBERG.

None of these workers, however, has gone the length of advancing a possible explanation of the large number of cases of irradiating pains of the sciatica type. Ruptures of disks into the vertebral canal have been too few in proportion to the number of sciatica cases, and reports on hypertrophy of the ligamenta flava are even rarer. Nor do advanced states of osteochondrosis and osteo-arthrosis, such as those seen on the radiograms of BÁRSONY and LASSILA, provide an adequate solution to the problem. No previous investigation can be said to have resulted in the formulation, »Sciatica means the rupture of a disk».

Material

The investigation includes both anatomic and clinical material. The former consists of the lumbar part of the vertebral column, obtained during postmortems from 160 cadavers of patients whose ages had ranged from 14 to 87 years, selected without reference to the clinical symptoms or the nature of the final illness. The latter comprises 732 patients who were subjected to radiographic examination of the abdominal organs and questioned regarding backache and sciatic pain in their past history. Patients visiting the hospital because of lumbago and sciatica were excluded.

The anatomic specimens were in most instances examined by dissection. The spinous process and the part of the arch furthest to the back were first sawn off so that it was possible to cut along the median line with a rib resector into the posterior wall of the dura. The roots of the arches were then cut off with the same instrument and the back wall of the vertebral canal could thus be removed in the form of a right and a

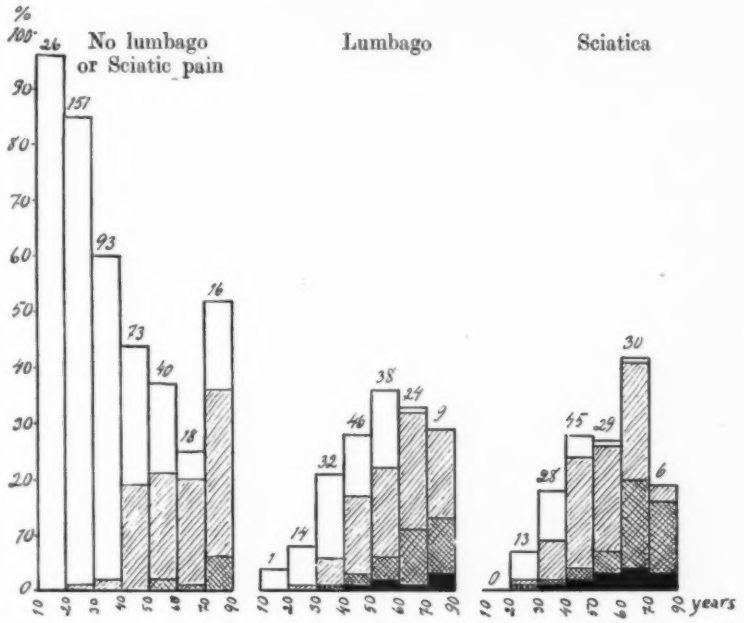
left piece. Bulges from the posterior wall were now compared with impressions in the dura, the roots and the nerves. The dural sac along with its contents and nerves was then dissected and lifted in one piece out of its bed, and elevations on the bottom of the bed were compared with depressions on the anterior part of the dural sac and the nerves. Finally, the intervertebral fibrocartilage was examined after a number of horizontal sections had been cut through each disk. Microscopic examination of the nerve specimens is at present being carried out and the results obtained will be published in a later paper.

In most cases, the anatomic specimens were radiographed before being dissected, in order that skeletal changes, calcified areas, the thickness of the disks, and the position and distribution of contrast fluids injected according to different methods could be studied. In 51 of the fresh specimens, red lead suspended in a gelatine solution had been injected into Luschka's cavity in the nucleus pulposus of the disks (after SCHMORL). The radiograms then showed whether the contrast medium had remained in a small area in the centre of the disk, in the normal way, or had flowed out into pathologic cavities. In 62 other cases, the specimens, after being removed, were subjected to epidural injection by puncture of the hiatus sacralis. The distribution of the contrast medium in the epidural tissues was visualized on the roentgen films. The epidural injections serve as a complement to corresponding injections made in the living subejct with perabrodil as the contrast agent. The results obtained from the last-named investigation are reported in another connection. The injections into the disks were also carried out (in 1939—1940), at first, with the intention of using them to complement injections into disks in living subjects, using perabrodil, but after a study of the literature had made it clear that a disk may rupture as a result of the lesion produced by lumbar puncture (PEASE), it was decided to refrain from the intra vitam part of the investigation. This decision was further strengthened by the fact that a later publication (KREUSCHER) confirmed the risks involved in puncturing the disks.

The study of the anatomic specimens was completed by examination of the hospital records and an enquiry among the relatives regarding back pain and sciatic symptoms. The enquiry was conducted almost exclusively through personal visits or by telephone, and only positive statements by persons who had been in close contact with the late patients were accepted.

Results obtained from the clinical series

Of the 732 patients, 164, or 22 per cent, stated that they had suffered from more or less severe lumbago, and 151, or 21 per cent, that in

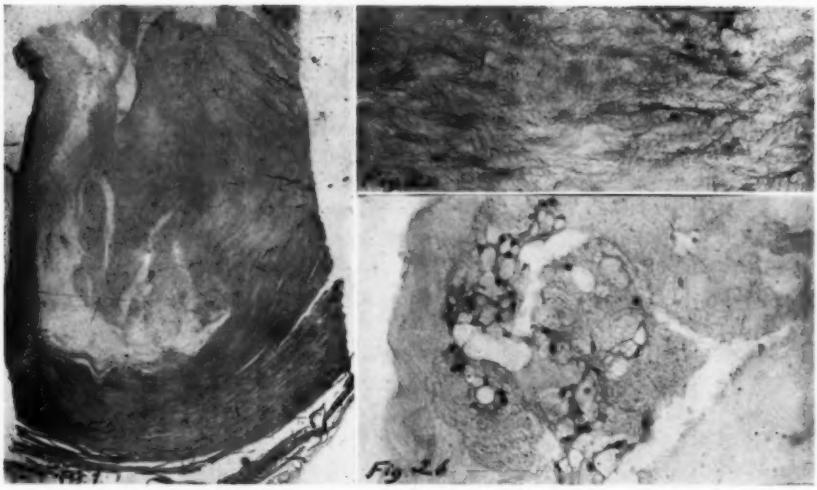


Diagrams 1—3. Clinical material in age distribution. Frequency of lumbago and sciatica and roentgenologic signs of disk degeneration (▨ = mild, ## = moderately severe, ■ = severe changes). The figures above the diagrams show the number of cases.

addition to backache, experienced in some cases, they had had symptoms resembling sciatica, or had been treated for sciatica. The other 417 patients, or 57 per cent, replied to the questions in the negative.

Diagrams 1—3 illustrate the age distribution of normal cases and cases of lumbago and sciatica. The incidence of radiographic signs of disk degeneration as visualized in the plain radiograms of the abdomen (usually anteroposterior views only) is also shown. The lesions in the disks seen on the films have been classified as *mild*, in which only small osteophytes were present at the margins of the vertebral bodies; *moderately severe*, showing fairly large osseous outgrowths and a possible reduction in the thickness of the disk; and *severe*, in which the disk was seen to have definitely collapsed.

It will be observed from the diagrams that lumbago and sciatic pain are extremely common complaints, and that they increase in frequency in the older age group. Another feature is that the radiographic signs of disk degeneration appear at an earlier age and in a more severe form in connection with lumbago than normally, and as regards sciatica the



Figs. 1—2 a and b. Microphotographs of the L. 5 disk of a girl aged 14. Note the fissures in Figs. 1 and 2 b. Compare the normal structure of the nucleus in Fig. 2 a with the pathological condition in Fig. 2 b.

difference is even more marked. Since the roentgenographic changes are dependent for their existence on the presence of disk degeneration, as was proved by the anatomic studies (see the following section), it follows that a causal connection can be assumed between disk degeneration on the one hand and lumbago and sciatica on the other.

Results obtained from the anatomic material

Disk degeneration. In conformity with the observations of SCHMORL, degenerative lesions in the disks were found to be very common, and in the older age groups they were even the rule. In the youngest case in the series, a 14 year old girl, there was already advanced degeneration of the lumbo-sacral disk (figs. 1 and 2), having the gross appearance of a fissure in the posterolateral segment, and under the microscope coming out as a local decrease in the staining capacity with groups of cells, lying in a reduced amount of intercellular substance, especially noticeable along the fissure.

In most instances, the degeneration in the disks was classified on the basis of the gross findings only. It was divided into two types, viz. degeneration I, an early stage including the change in colour and consistency usually described as brown degeneration, and fissures, in the main radially

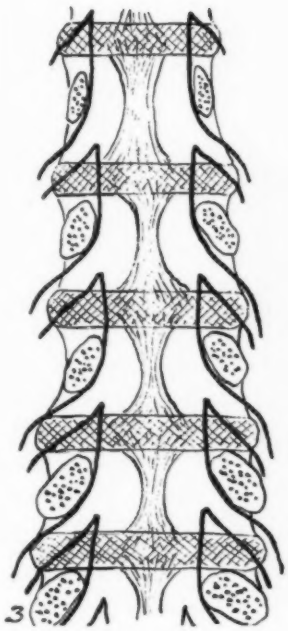


Fig. 3.

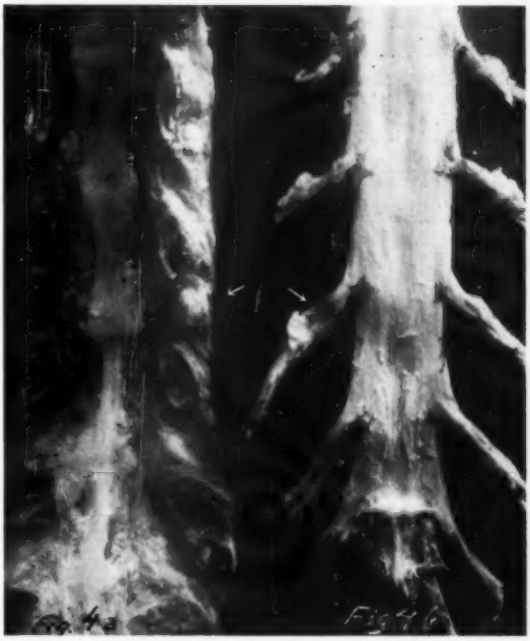


Fig. 3. Sketch of the location of the dural sac and the nerves in the spinal canal nd the intervertebral foramina.

Figs. 4 a and b. Photographs of an anatomic specimen showing a disk hernia(↗) into the third intervertebral foramen and the hollow(↗) into the corresponding nerve

arranged, which were nevertheless not sufficiently advanced to affect the general structure of the fibrocartilage; and degeneration II, the later stage in which the nucleus was more or less completely obliterated and new formations of connective tissue and bone had appeared.

Nerve compression. The degeneration was in many cases combined with abnormal bulging[1] of the fibrocartilage, and a bulge protruding in a backward or posterolateral direction was sometimes seen to be accompanied by compression of the dural sac and nerve roots, or of the ganglion and nerve. In comparison with the frequency of a compression of the dural sac and the cauda equina within the vertebral canal, compression of the nerves and ganglia was a strikingly common occurrence. Examples of the last-named type of compression were found on a level with the outer part of the intervertebral foramina at the point where the nerve pierces the plate of fibrocartilage belonging to the same segment (Figs. 3—4 a and b).

[1] In the remainder of this paper protrusion refers to the pathologic condition.

Diagram 4 illustrates the incidence, in various age groups, of nerve compressions and the degenerative changes in the fibrocartilage visible to the naked eye, and also the incidence of sciatic pain in the clinical series. It will be noted that the trend of the frequency curves is very similar in both series and that the curves relative to compression and to sciatica almost coincide at the beginning. The big drop in the sciatica curve in the older age groups may be due to forgetfulness on the part of the patients, and the same explanation may be at the back of the slow rise of the sciatica curve for the ages around 50 and 60 years. It is a fact that the more remote in time the symptoms are, the more difficult it is to obtain a satisfactory account of them. The patient is questioned regarding a backache and radiating pains in the legs, and the answer may be in the negative. But then, if the crossexamination is pressed, a reply of the following nature may be received: »Yes, I've had pains in my legs and back, of course, but that was rheumatism. It has been almost unbearable at times, especially when I had shingles there too». Thus, the actual frequency of sciatic pain can not be determined with certainty. One thing that is certain, however, is that the incidence of nerve compression is so high that no other explanation of the majority of cases of sciatica is needed.

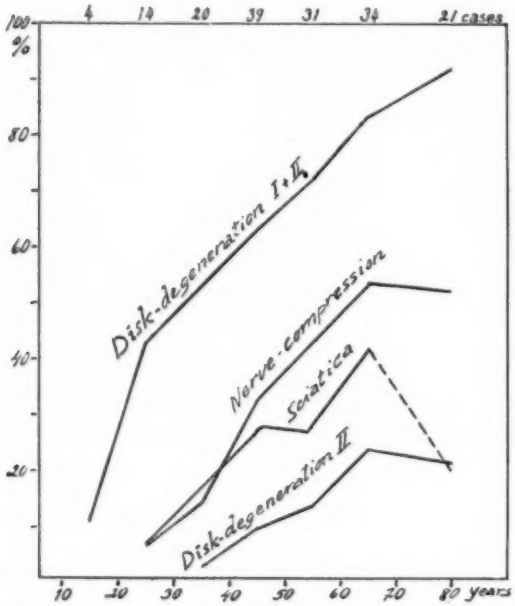
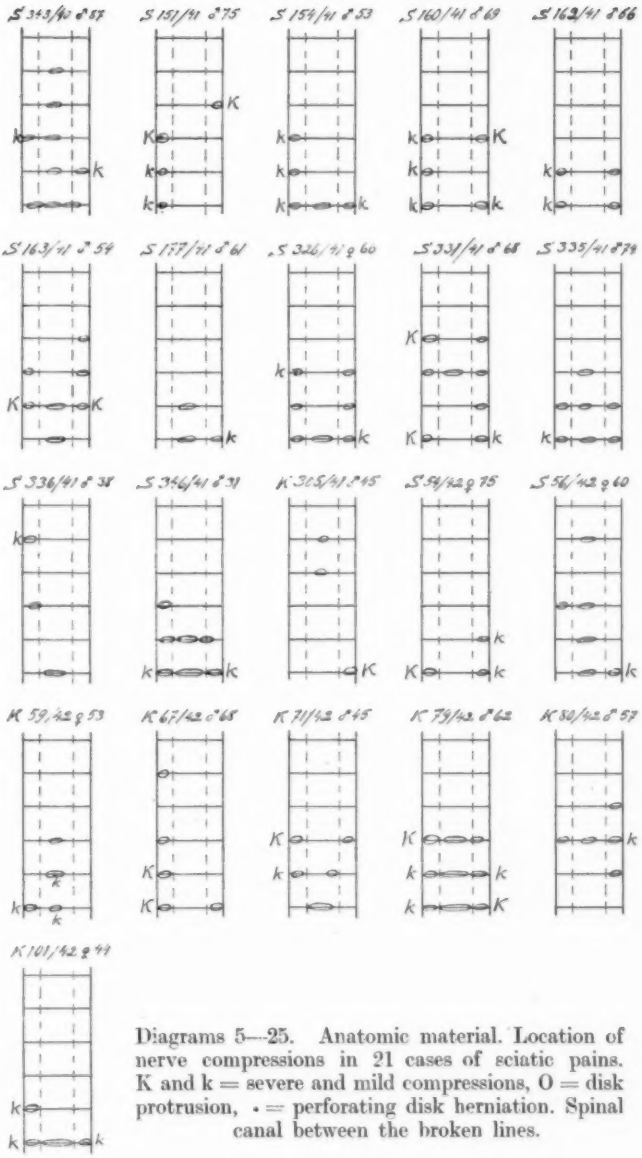


Diagram 4. Frequency of disk degeneration and nerve compression in the anatomic material and frequency of sciatica in the clinical series.

The study of the hospital records and the enquiry conducted among the relatives confirmed the fact that in the cases in which there was nerve compression there had also been symptoms of sciatica, at least in a great many instances. In three cases the records showed that the patients had received treatment to relieve sciatica, and in two cases there were statements to the contrary. The former patients had had nerve compression, and the latter had not. In 84 other cases contact was made with relatives



Diagrams 5—25. Anatomic material. Location of nerve compressions in 21 cases of sciatic pains. K and k = severe and mild compressions, O = disk protrusion, • = perforating disk herniation. Spinal canal between the broken lines.

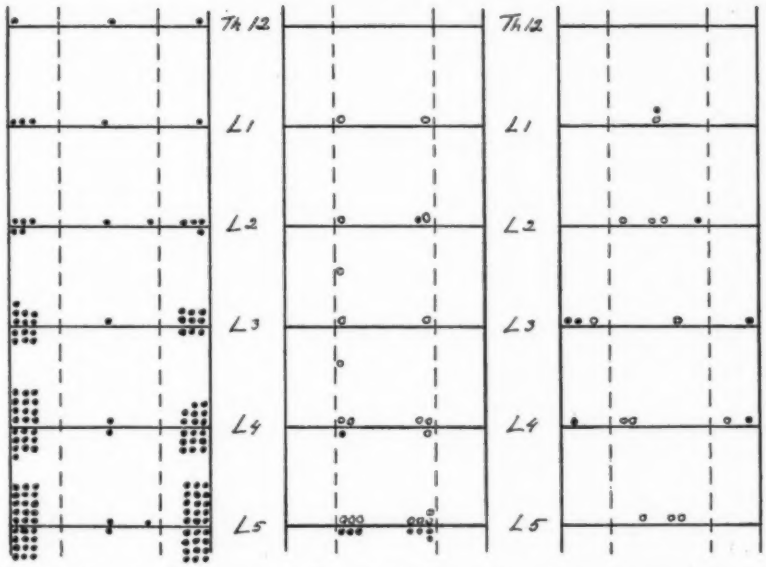
so closely connected with the patients that valuable information could be obtained. In 65 instances a negative answer was given; in 41 of these there had been no compression and in 24 a positive finding had been made With regard to 19 patients the reply had been yes, and in 18 of these compression of nerves was observed. In the 19th case, in which no compression was found, the patient had had symptoms in the hip joint with pains radiating out into the thigh which could very easily have been due to an affection of the hip joint.

In 21 cases the symptoms reported could be considered to indicate sciatica. They are shown in diagrammatic form on page 203. These cases derive from 89/160, or 56 per cent, of the material. This means that, if calculated on the basis of the entire material, reports of sciatic pain would have been received with regard to 37 to 38 cases. In comparison, the number of cases of compression was 60. The history supplied by the relatives must naturally be treated with an even greater reservation than the statements of the patients themselves, but it is an undeniable fact that a parallel can be drawn between the presence or absence of nerve compression and the replies of the relatives regarding the presence or absence of sciatica symptoms. The reservation is applicable to the negative answers, at least, as is shown by the case illustrated in figures 4 a and b. In this instance the protruded part of the third lumbar disk[1] was badly ruptured, compressing the nerve passing through it to a high degree, yet the relatives denied all knowledge of backache and sciatic pain.

The foregoing remarks are intended to illustrate the frequency and clinical significance of these nerve compressions. Brief mention of their location has also been made, but a complete survey is given in the diagrams on page 205. As has already been stated, in the large majority of cases the compressed segment was to be found on a level with the outer part of the intervertebral foramina, and was due to pressure exerted by the posterolateral parts of the protruded disks. In a few instances compression was observed within the vertebral canal, brought about by herniated layers of fibrocartilage, but in several cases there was also slight compression from behind which proved to be due to arthrotic lesions in the intervertebral joints. With one exception, pressure from behind was always accompanied by pressure from the front.

In diagram 27 the cases with bulging of the intervertebral joints and no nerve compression have been marked with circles. In only one instance were there actually impressions of the ligamenta flava, but the bulgings were uniform in all the interstices and exerted no pressure on the dura or the nerve roots. The uniformity suggests that an anomaly may have been in question. In no case was there genuine hypertrophy of the ligamentum flavum.

[1] The disks are named after the overlying vertebra.



Diagrams 26—28. Diagram 26: Location of anterior nerve compressions (•). Diagram 27: Location of protrusions of the posterior wall of the spinal canal with (•) and without (o) nerve compression. Diagram 28. Perforating disk herniations with (•) and without (o) nerve compression.

Objections have been raised against the interpretation placed by the writer on these nerve compressions. It has been suggested that they are the result of formalin hardening, and that the frequency of their occurrence has been exaggerated; further, the possibility of pressure from the front without any corresponding pressure from behind is considered questionable.

Formalin hardening in itself is unlikely to be the cause of the appearances brought about by these compressions, and the writer found an undoubted nerve compression even in the third of three fresh specimens under dissection. Furthermore, the microscopic appearance with respect to the cases examined is a proof that compression is not an artificially produced state.

The significance placed on the incidence of nerve compressions is determined by where one draws the line between the normal and the pathologic. I have regarded as normal those cases in which the disks were not protruded and the nerves were lying well embedded in fatty tissue with fatty tissue between the nerves and the plates of fibrocartilage (cf. Fig. 8). In these instances the nerves were round or oval in cross section

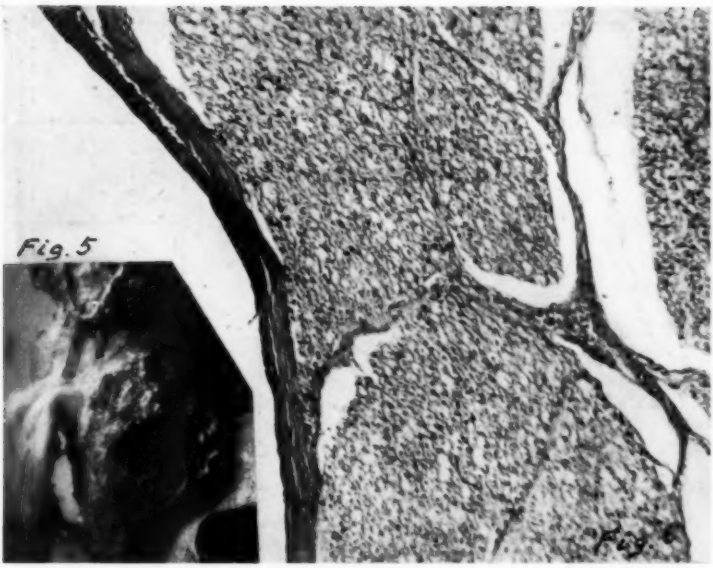
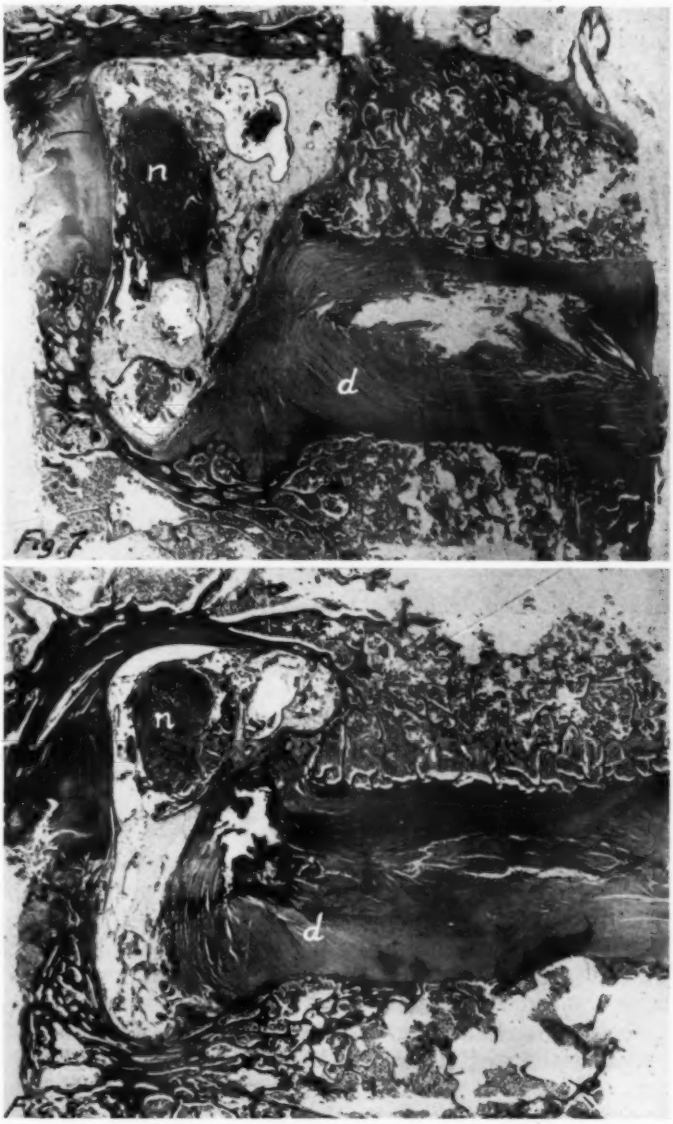


Fig. 5. Photograph of a compressed nerve, the medial part of it lifted. The arrow indicates fibrous adhesions to the nerve bed.
Fig. 6. Microphotograph of a cross section of a compressed nerve showing a sclerosed perineurium on the side of the compression.

with no aplaned surface facing the disk. This was the usual finding in young individuals. Nor were a number of cases, in which protrusion had occurred and the padding facing the disk was obliterated without the nerves having been deformed, counted as examples of compression. It was only when the surface of a nerve was definitely planed off against the forward bulge of a disk that compression was considered to be present. To these cases were added a few in which there were bowl-shaped depressions in the compressed nerves due to rupture, a predisposition to rupture, or osteophytes.

Pathologic fixation of nerves. In a great many cases displaying compression, the nerve was also abnormally fixed to the disk. The normally loose attachment was replaced by sclerotic connective tissue, such as is shown in figures 5 and 6. There is no doubt about the pathologic nature of these changes. A similar sclerotization was also observed in a few cases in which the tissue of the disk was pushing out under the ligamentum longitudinale posterius. In figure 7 there is illustrated a case in which



Figs. 7—8. Microphotographs of sagittal sections through two intervertebral foramina; above, a normal foramen showing the nerve (n) embedded in fat and loose connective tissue; below, a pathological foramen narrowed by the protruding disk (d) which touches the naked nerve (n).

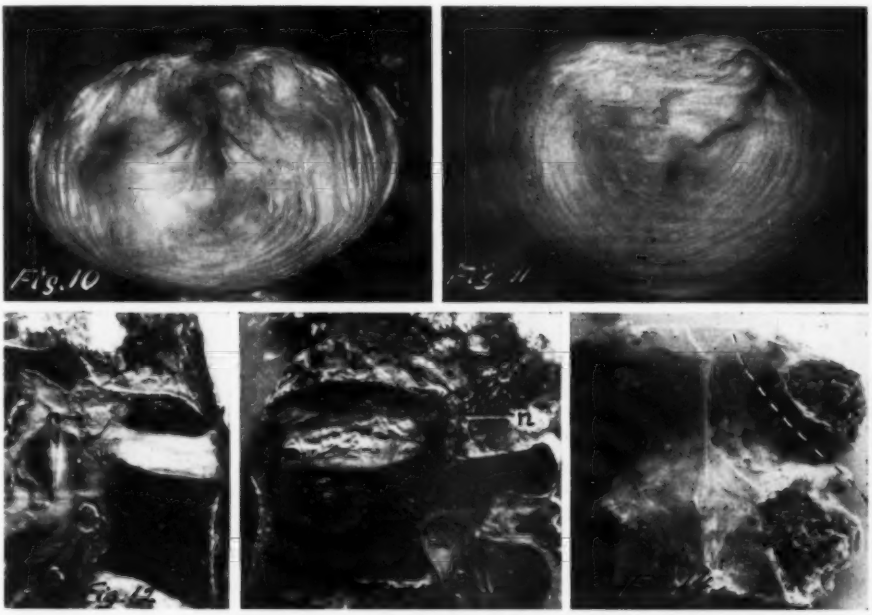
the ligament, which has grown into the dura, shows a high degree of thickening in connection with a dorsal herniation of the kind described.

The reason why the nerves in the intervertebral foramina can be compressed from the front only is in all probability that they pursue an arched course, with a forward concavity, and that they are incapable of being stretched. If the cauda is pushed backwards, the nerve roots must slacken, not tauten, because of the physiologic lordosis; but if a nerve is pushed backwards at its point of intersection with the disk it will be stretched instead. In this connection anatomic studies of Laségue's phenomenon, carried out by DANFORTH and WILSON, are of interest: »Flexion of the thigh with the knee extended causes a definite tightening of the fifth, fourth, and third lumbar roots»; thus, causing increased pressure on the corresponding disks.

Fig. 9. Photograph of a sagittal section through the posterior part of two vertebrae. Note the thickening of the posterior longitudinal ligament and the dura caused by a disk prolapse.

Radial fissures in the disks, protrusions, and ruptures. A study of the radial fissures in the disks (Figs. 8—11) is of assistance in accounting for the position and mode of origin of anterior nerve compression. Fissures could, of course, only be seen in disks which were not greatly changed, and the actual number originally present could thus not be determined. In the diagrams on page the location and the incidence of the fissures to be seen in the different disks are indicated, and figures are also appended showing the number of cases of advanced disk degeneration in which no fissure remains were distinguishable. The high frequency of fissures running backward and laterally in the lower three disks is especially interesting.

The radiating fissures were in many instances combined with local protrusion of the disk in the corresponding segment. The advanced disk degeneration was as a rule accompanied by general herniation. Sometimes, however, the same disk showed two or three radial fissures with corresponding protrusions of the disk. A bilateral protrusion of the posterolateral part of the disk as a result of corresponding bilateral fissures, was especially common. In some cases also, a radial fissure extended to the outer parts of the annulus fibrosus and then continued concentrically, usually in a lateral direction, causing a protrusion not immediately in front, but further to the side of, the primary fissure.

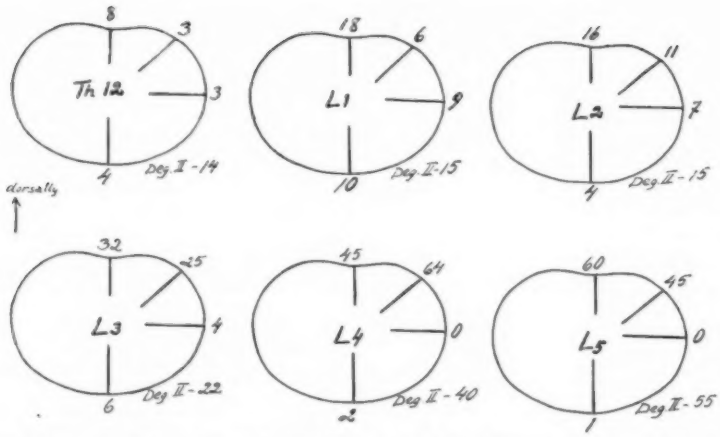


Figs. 10—11. Photographs of horizontal sections of two disks with radial ruptures in dorsal and dorso-lateral directions.

Figs. 12—13. Photographs of two intervertebral foramina in saw-sections at right angles to the directions of the corresponding nerves. To the left, a normal foramen. To the right, a pathologic foramen narrowed by a ruptured and protruding disk which is compressing the nerve (n).

Fig. 14. Photograph of the dorsal side of a sacralized vertebral body with a big osteophyte at the right portion of the hypoplastic disk between the sacrum and the sacralized vertebra. The broken line marks the course of the corresponding nerve.

In this connection it should be mentioned that five disks (in 4 cases) had *persisting epiphyses*. In all five disks there were fissures running toward the ventral aspect which continued on through the supposed epiphyseal cartilage. The »epiphyses» were at the most one centimeter in breadth. The observations agree with those of SCHMORL, and give added support to the view that these epiphyses are in reality separated from the margins of the vertebral bodies as the result of a secondary process (NIEDNER, and HAMMERBECK). Further evidence to the same effect was provided by another case. From a disk rupture within the substantia spongiosa on the dorsal aspect there was an offshoot to the dorsal side,



Diagrams 29—34. Direction and numbers of radial fissures in the different disks. Deg. II. with a figure means number of cases with a late stage of disk degeneration.

where it pierced the posterior surface of the vertebral body and spread out under the ligamentum longitudinale posterius, thus isolating the edge of the vertebral body.

Apart from ruptures into the spongiosa, the perforating herniations were rare in comparison with the protrusions. The ruptures were always allied to a local or general protrusion of the disk. Their numbers and position are shown in diagram 27. Only in five cases were they connected with nerve compression, one of these being within the vertebral canal. The rupture was large in one instance only, viz. that illustrated by figures 4 a and b.

In the inveterate cases, the protruded part of the disk was more or less ossified. Dorsal and dorsolateral osteophytes were observed in many of the radiograms, a fact worthy of closer attention than has hitherto been the case when diagnosis is being made on a living subject. In two cases with a hypoplastic disk between the fifth lumbar vertebra and the sacrum, there were large dorsolateral osseous outgrowths and nerve compression on one side, the remains of a protrusion. Thus, protrusion and compression of nerves are not precluded by hypoplasia of the disk; on the contrary, they seem to be a common complication after hypoplasia.

Sciatica without protrusion of disks. Among the anatomic specimens there was one which was not included with the other sciatica cases, despite the fact that the patient had had irradiating pains of the sciatica type. In this instance there was no pressure on the nerves from the disks

or intervertebral joints, but the ischiadic plexus was enclosed on all sides, and its trunks also to a certain extent, by sclerotic connective tissue. The case was that of a 29 year old woman who had suffered for ten years from a chronic infection starting as spondylitis or a paravertebral affection with abscesses alongside of the kidney, and complicated towards the end by amyloidosis and uremia. This case is a reminder of the fact that the postulate, »Sciatica means the rupture of a disk» is open to exceptions, in which the sciatic pain is attributable to quite different causes than protrusions of disks.

SUMMARY

An investigation on anatomic material, the preliminary results of which were reported in 1941, has been continued and supplemented with a clinical series, and has yielded the following information.

Symptoms of the sciatica type are a common occurrence and can be explained by the numerous examples of nerve compression observed in the anatomic specimens. These compressions are for the most part outside the vertebral canal, being situated instead at the outer part of the intervertebral foramina at the point of intersection between the nerve and the disk. In the large majority of cases the compression is due to the dorso-lateral protrusion of a disk. The protrusion in its turn is brought about by degeneration of the disks characterized by radial fissures, of which those running dorsolaterally play the chief part in producing compression of the nerves.

ZUSAMMENFASSUNG

Eine im Anschluss an eine frühere Arbeit vom Jahre 1941 vorgenommene Untersuchung an anatomischem Material in Verbindung mit einer Untersuchung an klinischem Material gab folgendes Resultat:

Beschwerden von Ischias-Typus kommen sehr häufig vor und lassen sich durch die zahlreichen Fälle von Nervenkompression erklären, die bei anatomischen Studien gefunden werden. Diese Kompressionen liegen grösstenteils ausserhalb des Rückenmarkkanals — sie befinden sich vielmehr in der äusseren Partie der Foramina intervertebralia, wo der Nerv die Zwischenwirbelscheibe kreuzt. Die Ursache der Kompression besteht in der grossen Mehrzahl der Fälle in nach hinten-lateral vordringenden Zwischenwirbelscheibenprotrusionen. Die Protrusionen werden ihrerseits durch Degenerationen der Zwischenwirbelscheiben und radiäre Fissuren verursacht, von denen die dorso-lateralen für die Entstehung von Nervenkompressionen die grösste Bedeutung haben.

RÉSUMÉ

Des recherches faisant suite à un travail antérieur de 1941 et portant sur un matériel anatomique avec adjonction de l'examen d'un matériel clinique ont donné les résultats que voici:

Les douleurs du type de la sciatique sont très communes et peuvent s'expliquer par les nombreux cas de compression nerveuse que les études anatomiques mettent en évidence. Ces compressions, pour la plupart, sont situées en dehors du canal rachidien et localisées à la partie externe des trous intervertébraux, au croisement du nerf et du

disque. Dans la majorité des cas elles sont dues à des protrusions postéro-latérales du disque. Ces protrusions, de leur côté, sont causées par des dégénérescences au sein des disques avec des fissures radiaires, parmi lesquelles celles qui sont dorso-latérales jouent le rôle le plus grand dans l'apparition des compressions nerveuses.

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FROM KARLSKOGA LASARETT, SWEDEN (SURGEON-IN-CHIEF: STIG LINDGREN, M. D.)

ADMINISTRATION OF CONTRAST MEDIUM IN UROGRAPHY VIA THE BONE MARROW[1]

by

Lennart Walldén

By urography is meant a roentgen examination of the urinary system after the infusion of a contrast substance, which is excreted through the kidneys. The synonymous name, intravenous pyelography, also indicates the way the contrast substance is introduced.

The great importance in modern medicine of venal puncture for diagnostic and therapeutic ends depends on the fact that its technique is as a rule rather simple. Sometimes, however, a necessary factor is missing: veins suitable for puncture. This may happen in cases of advanced obesity, pronounced anasarka, or circulatory collapse. In cases of widespread lesions, above all lacerations and burns in parts where suitable veins are usually to be found, and in patients who have had their veins destroyed by repeated transfusions, injections, and test punctures, venal puncture is usually impossible to perform. Intravenous technique often presents great difficulties also in children, above all infants.

In late years injections via the bone marrow have come into use in situations when intravenous injections are impossible for some reason or other. As early as 1934 ARNOLD JOSEFSON published examinations of injection of campolon through the sternum in cases of anaemia perniciosa. He thought that the effect achieved might possibly have been due to a specific stimulation of the bone marrow. Later researches seem to show that the result of intrasternal injection is identic with that of intravenous injection. BENDA, DEBRAY, and BOURIE (1937) injected bacteria into bone marrow of guinea pigs, and found the microorganisms in various organs almost immediately after the injection. More detailed studies in this field have been made by the Americans TOCANTINS and O'NEILL (1942). On injecting 5 cc of salt solution at one end of the femur

[1] Submitted for publication, Febr. 24, 1944.

of a rabbit they found that only about 2 cc reached the other end. Part of the fluid had disappeared into the surrounding blood vessels. Injections of contrast substance into the bone marrow of cadavers revealed the existence of near anatomical relationships between the vessels of the bone marrow and the general circulation. In a great number of clinical cases they could show the value of intramedullary technique for the administration of blood, plasma, and salt solutions.

This procedure does not yet seem to have come into a very general use in this country, but it has been tried in some hospitals with favourable results. It is often used at Karlskoga Lasarett for the injection of blood, plasma, and salt solutions, when the intravenous way is unavailable. It seems to be particularly valuable for injections in infants. While in adults the sternum is the easiest way of excess, it has seemed preferable in children, whose marrow cavity is too narrow, to use the long shaft bones, which contain red, vascular marrow. The tibia is the most accessible bone owing to its situation near the skin. Besides transfusions of blood, plasma, and salt solutions, intramedullary injection has also been used for the administration of sulphathiazole and heparin (LINDGREN and WALLDÉN, 1944). In such cases, with intermittent injection, this method has also the advantage that the needle can be left in place for a fairly long time. In cases of heparin treatment the needle has been left in the sternum for a week without any noticeable reaction in the surroundings. The active therapy of various exercises so important in thrombose treatment is also paid due regard to, since the patient is quite able to get up and move about with the needle left in his sternum.

The restrictions mentioned above of the use of venal puncture are often an obstacle to the roentgen examination of the urinary system. In such cases oral, rectal, subcutaneous, or intramuscular methods have been used, though only exceptionally has a sufficient concentration of the contrast medium in the urine been obtained. The iodine concentration required for a detailed examination is stated to be at least 2 % (HECHT). Human kidneys are able to excrete a urine whose total concentration of crystalloids is nearly five times that of blood. Experiments (VON LICHTENBERG and others) show that about the half ot this capacity is available for the excretion of a contrast medium after intravenous injection. A fluid quantity of 20 cc is supposed to be required for filling the two kidney pelves and the ureters with contrast — coloured urine, the necessity of evacuating the not contrast — coloured urine considered. If these 20 cc are to contain 2 % of iodine, a quantity of contrast medium containing 0.4 g of iodine is required. As 1,000 cc of blood per minute are supposed to pass through the two kidneys, an iodine concentration in the blood of at least 4 mg% is required for the above-mentioned parts of the urinary system to be filled up in about 10 minutes. The quantity

necessary to maintain this concentration for 10 minutes has been estimated at 0.6 g. As a matter of fact the doses really used in urography contains quantities of iodine considerably larger than those theoretically necessary. For a not inconsiderable resorption in the tissues is to be reckoned with. Fifteen minutes after an intravenous injection in man of 40 g of uroselektan TOURNÉ and DAMM found only 9 g in the blood. According to VON LICHTENBERG and HECKENBACH 6 g have been excreted into the urine after one hour. More than 25 g have accordingly been resorbed into the tissues after 15 minutes. A reresorption into the blood, however, takes place later, which appears as a considerably greater excretion of contrast medium than is accounted for by the diminishing of the quantity of contrast medium circulating in the blood.

The required blood concentration of the contrast medium is easily attained at intravenous administration. But if the resorption is to take place from the intestine or a tissue depot, the theoretically required minimum concentration is seldom attainable, so that a correspondingly longer period must pass for the excretion of the contrast urine. As a general rule comparatively useful pictures are obtainable after 45—60 minutes at oral, rectal, or subcutaneous administration. Intramuscular injection presents a more favourable aspect.

The present writer has recently made experiments with the administration of contrast fluid for urography via the bone marrow. A drawback of the intramedullary technique is that hypertonic or otherwise irritating solutions ought not to be used, since on injection they may provoke a strong reaction of pain and possibly hurt the bone marrow. The water-soluble iodine compounds generally used in urography are administered in very concentrated solutions at intravenous injections. Uroselektan B for instance, is used in a 75 % solution containing 50 % of iodine. This solution is hypertonic to a considerable degree and should not, accordingly, be used for intramedullary injections. An approximately isotonic solution which can be injected into the bone marrow without causing noticeable discomfort to the receiver is obtained only after a dilution with sterilized water at the ratio of 8: 1—10: 1. A quantity of this diluted solution ten times as large as that of the concentrated solution is accordingly required to administer to the organism the same quantity of contrast substance. The value of intramedullary injection, therefore, is decided with the question whether this large quantity can be injected in so short a time as to render the concentration in blood and urine sufficient for the necessary contrast in the roentgen picture. Instead of the usual quantity of up to 20 cc at intravenous injection a maximum quantity of 200 cc will have to be administered at intramedullary injection. The experiments carried out show that this demand for a sufficiently quick injection is well met. 200 cc are injected in 5

Fig. 1. Fig. 2. Fig. 3.

Fig. 1. Urogram taken five minutes after the beginning of the injection of 180 cc c:a 7 % solution of uroselektan B into the manubrium of the sternum in a 22 years old man.

Fig. 2. Urogram taken five minutes after the beginning of the injection of 60 cc c:a 7 % solution of uroselektan B into the tibia in a 2 years old baby.

Fig. 3. The contrast effect of the tibial, popliteal and femoral veins during the injection of a c:a 7 % solution of uroselektan B into the tibia in a 2 years old baby.

minutes through the sternum, in the tibia of infants a quantity adapted to the age of the receiver is administered in still shorter time. A picture taken five minutes after the beginning of the injection shows an excretion of contrast fluid quite as satisfactory as that after an intravenous injection, and the later increased intensity of contrast does not differ from that obtained at intravenous administration. (Figs. 1 and 2.)

The method is technically simple and does not bring about noticeable discomfort to the person examined. In adults the needle is inserted, after local anaesthesia of the skin, the subcutis and the periostium over the manubrium of the sternum as at ordinary sternal punctures. After it has been ascertained through a slight aspiration that the needle is in the marrow cavity, the contrast fluid, whose temperature should be that of the body, is injected. The patient, as a rule, has a feeling of tension in the sternum and towards the throat, but the discomfort is said to be a slight one. In children no irritation is seen except the uneasiness caused by the pricking in the skin necessitated by the anaesthesizing. The passage into the emissary veins of the diluted, rather weakly contrasting fluid is seen in fig. 3.

This form of injections, which has proved very valuable in cases when a quick administration of swiftly active substances is necessary and ordinary intravenous injection for various reasons cannot be performed, would seem to be no less important for the administration of contrast fluid at urography when venal puncture cannot be performed. Such cases, as is well known, are not uncommon. The method ought to be particularly valuable for urography in children.

SUMMARY

When intravenous injection of contrast fluid for urography is unsuitable, oral, rectal, subcutaneous, or intramuscular administration earlier has been tried but none of these methods has given a satisfactory contrast medium concentration in the urine. This, however, is fully obtained through a method of intramedullary injection of the contrast fluid elaborated by the author. As far as is known this way of administering contrast medium has never been tried before. The ordinary, strongly hypertonic contrast fluid solution must be rendered approximately bloodisotonic. The corresponding quantitative increase of the fluid administered comprises no diminishing in the urine of the contrast fluid concentration, since the injection of the required quantity can be carried out within few minutes. The pictures obtained are quite as good as those obtained at intravenous injection. The method would seem to be particularly valuable for urography in children.

ZUSAMMENFASSUNG

Wenn intravenöse Einspritzung von Kontrastmittel zur Urographie undurchführbar ist, sind orale, rektale, subkutane und intramuskuläre Zufuhr früher versucht worden, aber keine dieser Methoden hat eine befriedigende Kontrastmittelkonzentration im Harn gegeben. Letztere wird jedoch durch eine von Verf. ausgearbeitete, intramedulläre Injektionsmethode für Kontrastmittel vollgut erzielt. Soviel man weiss, ist dieser Weg der Kontrastmittelzufuhr bisher noch nie versucht worden. Die gewöhnliche, stark hypertone Kontrastmittellösung muss annähernd blutisoton gemacht werden. Die entsprechende mengenmässige Zunahme der zugeführten Flüssigkeit bringt keine Abnahme der Kontrastmittelkonzentration im Harn mit sich, da die Einspritzung der erforderlichen Menge in wenigen Minuten durchgeführt werden kann. Die erzielten Bilder sind durchaus ebensogut wie die mit intravenöser Injektion erhaltenen. Die Methode erscheint als besonders wertvoll für die Urographie bei Kindern.

RÉSUMÉ

Lors d'empêchements à l'injection intraveineuse du liquide opacifiant de l'urographie on a essayé jadis de l'administration buccale, rectale, souscutanée ou intramusculaire mais aucune de ces méthodes n'a donné une concentration suffisante de la substance de contraste dans l'urine. Pareille concentration, en revanche, s'obtient parfaitement bien par un procédé d'injection intramédullaire que l'auteur a mis au point. Autant qu'on le sache, ce mode d'administration de la substance opacifiante n'a jamais été essayè antérieurement. La solution ordinaire, qui est fortement hypertonique, doit être rendue approximativement isotonique au sang. L'augmentation correspondante

de la quantité du liquide introduit n'entraîne aucune diminution de la concentration de la substance opacifiante dans les urines étant donné que l'injection du volume nécessaire peut se faire en l'espace de quelques minutes. Les images obtenues sont tout aussi bonnes que celles obtenues par injection intraveineuse. Il semble que la méthode doive être particulièrement précieuse pour les examens urographiques chez les enfants.

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT OF THE CAROLINE HOSPITAL, STOCKHOLM
(HEAD: PROFESSOR Å. ÅKERLUND)

MILIARY TUBERCULOSIS AFTER RETROGRADE PYELOGRAPHY[1]

Report of a case

by

Åke Lindbom

If, in retrograde pyelography, too large an amount of contrast medium is injected, a backward flow into the renal tissue through a fornix rupture may easily occur producing a so-called *fornix backflow*. If large amounts are injected, the contrast medium may even continue into the veins creating a *pyelovenous backflow*. Direct communication is then established between the pelvis of the kidney and the blood system. If, in cases of pyelovenous backflow, bacteria are present in the renal pelvis, these can follow along into the blood stream. Under certain circumstances, retrograde pyelography can therefore be as fatal as an intravenous injection of bacteria.

For this reason, many urologists warn against retrograde pyelography in instances where the renal pelvis is infected, as one can never be sure of preventing a backflow even if the greatest care is taken. The danger of retrograde pyelography in cases of suspected renal tuberculosis is especially pointed out and stress is laid on the subsequent risk of miliary tuberculosis. Retrograde pyelography is therefore done unwillingly or not at all in cases of suspected tuberculosis of the kidneys by CLAIRMONT, HINMAN and RUBRITIUS. Most urologists and roentgenologists seem, however, to perform retrograde pyelography without hesitation on cases of renal tuberculosis. Note, for example, the textbooks of SCHINZ and SHANKS. BRAASCH has performed retrograde pyelography on 100 cases of renal tuberculosis without any fatal outcome. With the exception of the author's case, 20 retrograde pyelographies have been made at the Caroline hospital on unquestionable cases of renal tuberculosis with no

[1] Submitted for publication, Jan. 25, 1944.

ill effects on the patients. In literature, the author has not been able to discover any case of miliary tuberculosis directly connected with retrograde pyelography.

On the other hand, several instances of post-traumatic miliary tuberculosis have been described. According to ZOLLINGER who has summarized the literature on the subject, it is generally recognized that miliary tuberculosis can sometimes develop after a trauma. This is said to occur when a tuberculous herd post-traumatically invades the bloodstream. ORMOND, for example, published a case of prostatic tuberculosis which died from miliary spreading 13 days after prostatectomy. According to ZOLLINGER who bases his statements on several authorities, death should occur at the earliest 10 days, and at the latest 60 days after trauma in order to confirm a definite connection between trauma and miliary tuberculosis. Generally, the space of time between trauma and death is approximately 3 weeks.

The author's case

A 70 year old man was admitted into the Caroline hospital for bladder trouble. 8 years previous, he had suffered from exudative pleurisy on the left side. For the last several months, he had had frequent urination night and day. A roentgenogram of the lungs showed a pleural adherence at the base of the left lung, but no other pathologic sign. Numerous red and very many white blood cells as well as acid-fast bacilli were found in the urine. Staphylococcus albus grew abundantly in the culture of catheterized urine. Urography (intravenous) showed conditions to be normal on the right side, but such poor contrast excretion on the left side that no details could be distinguished. In order to study the left kidney pelvis more closely, a retrograde pyelography was made on this side by means of a catheter according to Chevassu. An unusually large quantity of contrast medium was injected without the patient complaining of pain. The kidney pelvis was found to be dilated with large calices. At least one calix seemed to lead into a cavern (figure 1). The ureter was also highly changed by its ragged contours (figure 2). In a couple of pyelograms taken several minutes later, an obvius contrast filling of the *right* renal pelvis and the upper part of the right ureter was visible (figure 3). From a picture in which one could see that no contrast medium had reached the bladder, it was clear that no contrast medium had forced its way in a retrograde direction up through the right ureter. The contrast fluid must therefore have been excreted by the blood into the right renal pelvis. Although no pyelovenous backflow could be seen in the left side pyelogram, a severe backflow must have occurred giving almost as good a picture of the kidney right pelvis as an intravenous urogram.

The day after the pyelography, the patient's temperature rose sharply. During the next few days it fell only to rise slowly again after three days. On the 14th day after the pyelography, a new pulmonary röntgen picture was taken. This showed a typical picture of miliary tuberculosis, developed since the lung examination made the day before the pyelogram. The temperature increased further. The patient became weaker and died 21 days after the pyelography (see figure 4).

Post-mortem examination showed left-sided renal tuberculosis with a number of ulcers on the papillary summits and a cavern the size of a green pea in the forward middle part of the kidney. The entire length of the ureter had undergone an acute tuberculous

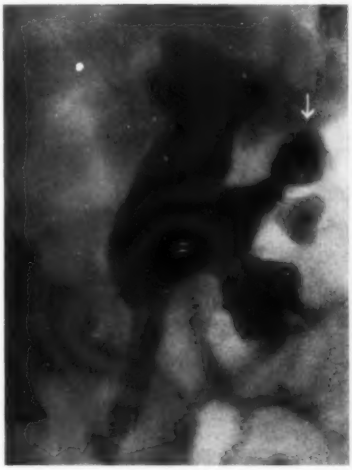

Fig. 1.

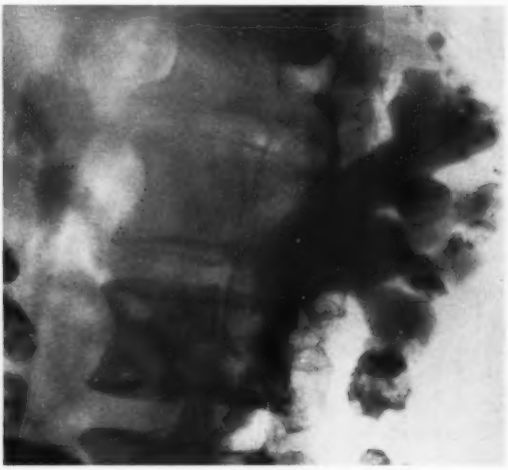

Fig. 3.

Fig. 2.

Figure 1. Retrograde pyelography. Greatly dilated renal pelvis with large calices. The arrow points to a cavern. Tuberculous changes.

Figure 2. Severe tuberculous ureteritis. (Barium contrast medium in the intestines).

Figure 3. Retrograde pyelography on the left side. Distinct secretion of contrast liquid into the right renal pelvis. (Barium contrast medium in the intestines).

change with caseous necrosis. Miliary tubercles were found in the liver, spleen and both kidneys. The lungs were also studded with tubercles, but no changes could otherwise be noted. The microscopic picture of the pulmonary tubercles showed that these were of recent date. Giant cells were lacking and the cells in the tubercles were largely made up of leukocytes.

Epicrisis: During retrograde pyelography, an acute pyelovenous backflow took place in a patient suffering from one-sided, serious, renalureteral tuberculosis. A large quantity of the bacteria-rich content of the renal pelvis came thereby directly into the blood. The patient died from miliary tuberculosis 3 weeks after the pyelogram was taken.

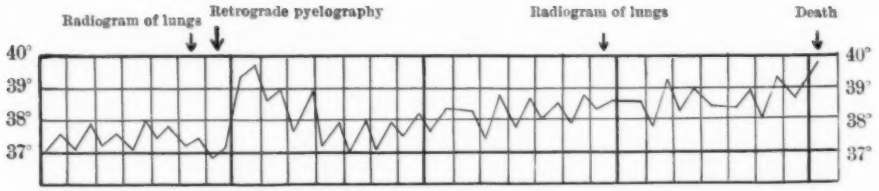

Figure 4. Temperature curve.

It is therefore most likely that the miliary tuberculosis in the author's case was caused by retrograde pyelography.

Although, judging from literature, the risk of this complication from retrograde pyelography is very small, the above-described case shows that the risk does exist. To completely give up retrograde pyelography of kidneys suspected of tuberculosis is hardly advisable as this method of examination gives exceedingly worthwhile results. Urography (intravenous) does not supply any real information as to the renal pelvis in cases where the kidneys secrete insufficiently. In instances where the renal pelvis and therefore also the urine contain large numbers of bacteria, there is a great risk that a possible backflow might be followed by complications.

The following rules are advisable to follow: in those cases where tubercle bacilli are found in smears of urinary sediment, retrograde pyelography of the suspected kidney should be avoided. In cases where tuberculosis is suspected but tubercle bacilli are not found in smears of urinary sediment, retrograde pyelography can be made, care being taken during injection. In spite of great caution, backflow is nevertheless not completely avoidable.

SUMMARY

The author reports on a case of miliary tuberculosis following retrograde pyelography and draws the conclusion that retrograde pyelography should not be made on the suspected side in cases where tubercle bacilli are found in smears of urinary sediment.

ZUSAMMENFASSUNG

Verf. berichtet über einen Fall von Miliartuberkulose nach retrograder Pyelographie und zieht den Schluss, dass bei Fällen, wo im Abstrich des Harnsediments Tuberkelbazillen gefunden werden, die retrograde Pyelographie auf der verdächtigen Seite nicht vorgenommen werden sollte.

RÉSUMÉ

L'auteur rapporte un cas de tuberculose miliaire succédant à une pyélographie rétrograde et en conclut que celle-ci ne devrait pas être pratiquée du côté suspect lorsqu'on trouve des bacilles de Koch dans les frottis du sédiment urinaire.

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FROM THE RADIUM CENTRE, COPENHAGEN (CHIEF: DR. JENS NIELSEN)

A SIMPLE DEVICE FOR THE CONTINUOUS CONTROL OF ROENTGEN-RAY OUTPUT[1]

by

Sv. Hoeffer Jensen

An essential feature of roentgen therapy is the constancy of the output from the roentgen tube. Such constancy is generally assured by measurements of the intensity made from time to time, and it is then tacitly assumed that if consecutive measurements do not differ from each other, the output has been the same during the intermediate period.

Apart from the obvious shortcomings of such an assumption, another serious error of judgement is often introduced by the measurements, which as a rule are made only in one direction, viz. the axis of the exit cone of the rays. If the intensity is lessened in a part of the exit cone, for instance by deterioration or loosening of the tungsten dish on the anode, this may not be detected by the usual measurements and may yet be of clinical importance.

Such a lessening of intensity may, however, be detected by measurements of the total flux of roentgen rays. An instrument designed for such measurements should therefore prove of value not only to hospitals with large installations, but perhaps even more to the practitioner with only one tube, provided it be constructed so as to be robust, constant, easy to handle, cheap and does not interfere with the treatment, It should, then, as far as possible, be affixed to the roentgen tube itself.

An apparatus which fulfils these conditions has now been in use for several months on an roentgen-ray outfit in the Radium Centre in Copenhagen. As it has been proved to be dependable a description of it may be of interest to others. It consists of two parts: 1) ionisation chamber, and 2) the amplifier (with instrument).

The ionisation chamber has been built onto the tube in the manner shown in Fig. 1, which shows a section through the exit piece of the well known Siemens Tuto-case. This is usually closed by a window of

[1] Submitted for publication, April 19, 1944.

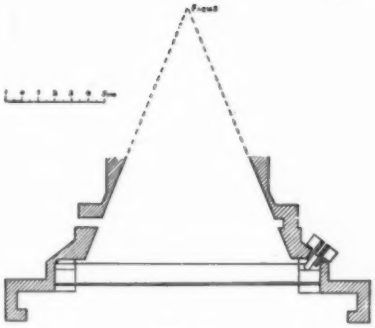

Fig. 1.

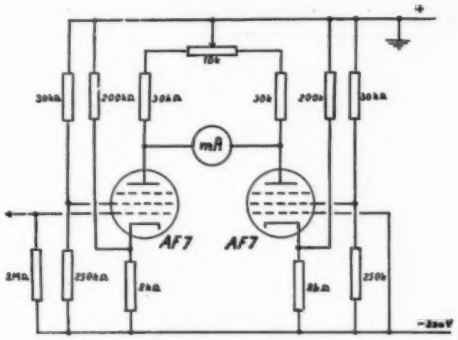

Fig. 2.

cellophane fitted into a recess. This recess is, however, cut so deep that it affords ample space for the mounting of the ionisation chamber. The cellophane diaphragm is removed and replaced by an aluminium foil, 0,1 mm thick, mounted on small hard rubber blocks. By means of an insulated bushing through the metal of the Tuto-case this foil is connected to the amplifier and thus acts as the insulated electrode in the ionisation chamber. The other electrode, which is grounded, consists of the cellophane window — which is replaced in the recess about 10 mm in front of the aluminium foil — plus the outer metal of the Tuto-case. The cellophane is painted with graphite to make it electrically conducting.

With the exception of the mA-meter and the zero-control resistance, which are affixed to the wall within view of the control table of the roentgen-ray outfit, the amplifier is housed in a small cupboard placed in the therapy room. The circuit is shown in Fig. 2. It is fed directly from the ordinary A. C. mains, and also provides the tension for the ionisation chamber. To eliminate random changes it has been made in the form of a bridge.

If the tube gives an output of 30 r/min at a distance of 40 cm. one may easily get a reading of about 2 mA on the meter. Even a deviation of a few per cent can thus easily be ascertained.

It is, of course, not to be expected that such an apparatus should be independent of the wavelength. In fact, it is not; but the dependence is only slight and does not matter, because the apparatus is intended only as control instrument. The meter may be divided to read r/min directly, but the scale is then only valid for a fixed filter. As the intensity varies with the filtering we get extra a filter-control.

The gaugeing is very constant; which is probably due to the robustness of the chamber, mounted as it is on the Tube-case. This mounting

also brings it out of the way, so it does not interfere with the treatment. The daily attendance consists only in switching the amplifier on and off and adjusting the zero-point of the instrument.

A small disadvantage is the additional filtering by the aluminium foil in the chamber. This is, however, in most cases insignificant, since the initial filtering of the roentgen tube amounts to about 1.5—2 mm Al. Care should, of course, be taken to mount the chamber in such a way, that all thicker parts are hid in the recess and do not shadow out any part of the main cone of roentgen-rays.

The apparatus can probably at the present time be built for about 350 Danish Kroner. Of this amount about 100 Kroner fall on the instrument (mA meter), another 100 Kroner on the ionisation chamber. By chosing a smaller size mA meter and saving a little here and there the cost may be pressed down to about 300 Kroner. It is, of course, possible to use one amplifier for two or more tubes alternately, but this destroys the original principle of constant control over the output of roentgen-rays. As the cost is reduced only comparatively little by such a measure, it should, if in any way possible, be avoided.

SUMMARY

An uneven intensity distribution within the cone of rays from a Roentgen tube may seriously hamper the treatment. It can be detected by measurement of the total flux of Roentgen rays. A description is given of an apparatus, which makes possible a simple and continuous control of this flux.

ZUSAMMENFASSUNG

Ungleichmässige Verteilung der Intensität des Strahlenkegels einer Röntgenröhre wird für die Behandlung grosse Nachteile mitsichbringen. Sie lässt sich durch Messung der gesamten Strahlenmenge der Röhre auffinden. Es wird ein Apparat beschrieben, der diesbezüglich eine einfache und dauernde Kontrolle ermöglicht.

RÉSUMÉ

Une distribution d'intensité irrégulière dans le cône de rayons d'un tube de Roentgen peut gravement nuire au traitement. On peut la découvrir par mensuration de la quantité totale de rayons du tube. L'auteur décrit un appareil, qui rend possible un contrôle simple et continu.

FHOM THE ROENTGENOLOGICAL DEPARTMENT, CAROLINE HOSPITAL (KAROLINSKA SJUKHUSET), STOCKHOLM. (HEAD: PROFESSOR Å. ÅKERLUND)

ON THE ROENTGEN DIAGNOSIS OF CHOLESTEATOMA IN THE TEMPORAL BONE[1]

by

Sölve Welin

In cases of otitis media chronica we differentiate between those with central perforations of the tympanic membrane and those with marginal. In the former there is hardly any need to think of cholesteatoma, while in the latter it is necessary to bear that affection in mind whether the perforation is directed upwards towards the attic or backwards towards the antrum.

The clinical symptoms of cholesteatoma may vary considerably. Occasionally there may even be a complete lack of symptoms for a long time. Owing to the liability of the disease to spread to adjoining vital organs, however, an *early diagnosis* is of the utmost importance.

The Roentgen method of examination, which is based on the bone-destroying effect of cholesteatoma, has also been employed for this diagnosis. By themselves, cholesteatomata do not produce any pathognomic changes demonstrable by Roentgen — at least, none have so far been observed. Cholesteatoma can thus not be diagnosed from a radiogram until bone destruction has set in.

The Roentgen method of diagnosing cholesteatoma was originally considered easy; experience soon showed that this is by no means so, however, but may rather — as in acute otitis — involve great difficulties. This is especially considered to apply to cholesteatomata situated in pneumatized temporal bones.

As early as in 1914 SONNENKALB wrote in his large monograph »Röntgen-diagnostik des Nasen- und Ohrenarztes» that he could recognize a cholesteatoma cavity in an Roentgen photo when it had exceeded a certain size. Since then the diagnostics have been considerably improved, chiefly perhaps by Dr. E. G. MAYER of Vienna, who has written several

[1] Submitted for publication, Febr. 10, 1944.

papers dealing with these problems. Of Scandinavian physicians engaged in research work in this field may be noted GÖSTA RUNSTRÖM and YNGVE OLSSON from Sweden and KNUT BRÖSTE from Denmark.

The sharp definition, angularity, and polygonal shape of cholesteatoma cavities, their occurrence in temporal bones with reduced pneumatization, and — as a sign of proliferative reaction — a linear calcareous zone between them and the surrounding bone tissue, have so far been held to be characteristic of these cavities.

Several research workers have concurrently strongly emphasized that in these cases the adequacy of Roentgen examinations must not be overrated, and that only a positive Roentgen find constitutes definite proof; a negative result of a Roentgen examination does not justify the conclusion that there is no cholesteatoma.

The following survey will show from what changes discernible in radiograms cholesteatoma cavities are diagnosed at this hospital, and to what extent such a diagnosis is possible in a clinical material.

Our material consists of 109 roentgenologically examined cholesteatoma patients operated upon in the Ear Clinic of the Caroline Hospital from $^{1}/_{1}$ 1940 to $^{1}/_{10}$ 1943. Of these, 5 had double-sided cholesteatomata, 54 only on the right side, and 50 only on the left. The number of cholesteatoma-affected ears examined is thus 114.

The Roentgen examination was made in direct conjunction with the operation, and the interval between Roentgen examination and operation was in no case long enough for any roentgenologically noticeable changes to have occurred.

The same roentgenological method was used throughout the period of the investigation. We were using the projection-combination proposed by RUNSTRÖM in 1931, supplemented by the symmetric projection suggested by ALTSCHUL, which shows both the mastoid processes in antero-posterior rays and gives an excellent general idea of conditions in the mastoid process. Dr. HOLMES, in America, holds the same views, and uses an almost identical projection. In a paper published in 1938 he pointed out that an antrum enlargement can be diagnosed earlier with this projection than with any other. He was able to demonstrate an enlarged antrum by this projection in 165 cases, in all of which the operation disclosed bone-destroying cholesteatomata.

In one of my own cases the operation revealed a pea-sized cholesteatoma matrix in the most anterior part of the epitympanic recess, although there was no roentgenologically demonstrable change, the richly developed cell system showing normal air contents and plenty of lime in all the cell septa, even in those situated in the epitympanic recess. Nor was any destruction visible.

In all other examined cases of cholesteatoma roentgenological changes in the form of reduced air and lime contents or destructive processes were found.

20 of our 114 ears presented no roentgenological indications of cholesteatoma. In 11 of these 20 the bone was not pathologically affected — at least as far as can be judged from the 1940—1942 operation reports and from what I personally have seen in 1943.

In 8 cases the operator found only cholesteatoma flakes or rice-grain sized cholesteatomata in the attic, and in 3 cases merely cholesteatoma flakes in the antrum; in these cases no changes indicating cholesteatoma could of course be expected in the Roentgen photos.

In the 9 remaining cases, on the other hand, cholesteatoma cavities as large as peas were found in the attic 5 times, and up to bean-sized cavities 4 times outside the antrum in pneumatized temporal bones.

This proves that a destruction must have reached a certain size before it will show in the radiogram.

The following Table has been drawn up to show the degree of pneumatization in these cases.

Table

Extensive pneumatization.	Average pneumatization.	Slightly reduced pneumatization.	Strongly reduced pneumatization.	No pneumatization.
1	8	18	47	40

The material is, as suggested by SCHWARTZ, arranged in 5 different groups according to types of pneumatization. In these chronic cases irregularity does not — at least in our experience — seem to make any difference, in contradistinction to what it does in cases of acute otitis, and no distinction has therefore been made in the Table between regular and irregular cell-groups.

The Table shows that the large majority of the cases belong to the »strongly reduced» or »no pneumatization» groups, which is what might be expected, as they are all chronic cases of otitis. Further, cholesteatomata have also been found in the »slightly reduced» group, in the »average» group and in one case even in an extensively pneumatized mastoid bone. This, too, has long been known, and implies no new discovery.

According to the localization of the cholesteatoma cavities we differentiate between cholesteatomata in the aditus ad antrum, in the antrum, and in the attic.

Cholesteatomata in the Aditus ad antrum

The most important, and at the same time most common, roentgenological indication of cholesteatoma is in our opinion the pathological enlargement of the *aditus ad antrum*.

The anatomical and topographical details of the aditus may be seen in Fig. 1, which is a photo of a section through the temporal bone parallel to the mastoid plane. In the photo can be seen that there are cells and cell septa on the superior and lateral walls of the aditus, and that the upwardly convex, rounded margin of the innermost part of the strikingly broad posterior wall of the auditory meatus forms the inferior wall of the aditus. To the Roentgenologist the aditus is thus a bony canal a couple of millimetres broad.

Fig. 1. Photo of a section through the temporal bone, showing cells on the lateral and superior aditus walls and the rounded upper margin of the strikingly broad posterior wall of the auditory meatus.

In our material the aditus was pathologically enlarged in no less than 68 cases. In some of them the change consisted merely in a hardly demonstrable planing down of the innermost portion of the posterior wall of the auditory canal, or in an infinitesimal usure on the lateral and superior walls of the aditus. Such usures have usually — as shown in Fig. 2 — rounded, backwardly convex, distinct margins. In these cases the cholesteatoma cavities are, generally speaking, rounded, and thus not of the angular form previously said to be characteristic of cholesteatoma destructions. In other cases the inner portion of the posterior wall of the auditory canal may be almost completely destroyed (Fig. 3), permitting the cholesteatomata to be discharged directly into the external auditory canal; this may be called a spontaneous radical operation.

In practically half of our cases cholesteatoma was diagnosed solely on changes in the aditus.

But these changes do not permit any conclusions to be drawn regarding the extent of the cholesteatomata, as these may reach far forward in the tympanum or backward in the antrum without causing any further roentgenologically demonstrable destructive changes.

Fig. 2 a.

Fig. 2 b.

Fig. 2. *a*. Pathological enlargement of the aditus due to a planing down of the posterior wall and a usure on the lateral wall of the auditory meatus. *b*. The healthy ear of the same patient.

Fig. 3 a.

Fig. 3 b.

Fig. 3. *a*. Pathological enlargement of the aditus, showing a large cavity in the place of the antrum. *b*. The healthy ear of the same patient.

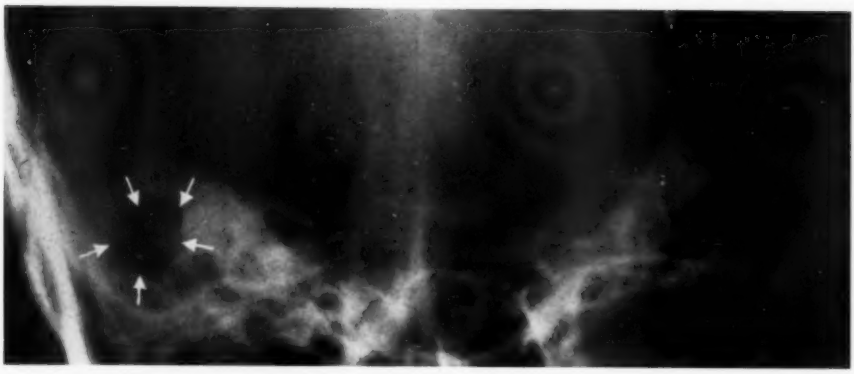

Fig. 4. Picture in Altschul's projection. Antrum cholesteatoma in a non-pneumatized mastoid bone.

Fig. 5 a. Fig. 5 b.

Fig. 5. The same case in Runström's 2nd projection. *a*. The diseased ear. *b*. The healthy ear.

Cholesteatomata in the Antrum

From the point of view of Roentgendiagnosis we differentiate between cholesteatomata in non-pneumatized temporal bones and in pneumatized temporal bones. In the firstnamed, a diagnosis can as a rule not

Fig. 6. Picture in Altschul's projection. Practically no pneumatization. Erroneously diagnosed as cholesteatoma.

Fig. 7. The same patient in Runström's 2nd projection.

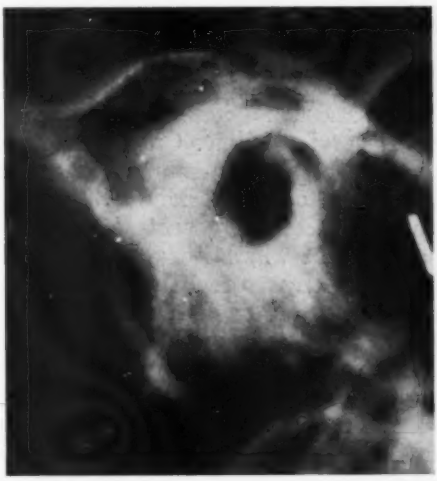

Fig. 8. The same patient in Runström's 1st projection.

be set by means of Roentgen examinations until the destruction has become rather extensive (unless there is also a pathological enlargement of the aditus). In such cases a correct and early diagnosis will largely depend on the experience of the examinator, for the size of a normal antrum may vary considerably. An antrum which by one doctor is considered enlarged may by another be thought normal.

Fig. 4 shows an antrum cholesteatoma in a non-pneumatized cell system. This is a radiogram in ALTSCHUL's projection. Instead of the antrum, we see here a pathologically large cavity of distinctly rounded outline.

Fig. 5 — a radiogram of the same patient in RUNSTRÖM's 2nd projection — the distinct boundaries of the cavity can be observed even more clearly, and the characteristically linear calcareous zone, which according to some doctors is a result of tissue reaction to the irritation of some foreign body, something like the formation of new bone round a bullet or metal pin.

In this case the inner portion of the posterior wall of the auditory canal has moreover been so extensively destroyed that a considerable pathological enlargement of the aditus can be seen, which further supports the cholesteatoma diagnosis.

The difficulties of differentiating in the diagnosis between cholesteatoma and a total absence of pneumatization are illustrated in Fig. 6—8, obtained from a case erroneously diagnosed as cholesteatoma of the antrum. The patient, a woman of 44, had for 3 years suffered from increasing dizziness, headaches, and tinnitus. For the last year she had also had gait disturbances of a cerebellar-atactic type. She was therefore admitted to a neuro-surgical clinic. On being examined there, a marginal perforation of the tympanic membrane, with positive fistula test, was discovered. After a Roentgen examination cholesteatoma was diagnosed and the patient accordingly sent to our ear clinic for operation. There being some doubt whether the Roentgen diagnosis was correct, the Roentgen examination was repeated. In the radiogram (Fig. 6) an even-contoured cavity was observed in the place of the antrum. There was no definite pathological antrum enlargement, however, the size of the cavity being quite well within the normal range. On a picture in RUNSTRÖM's 2nd projection (Fig. 7) some small cells and cell bulges appeared around the antrum. The boundaries of the latter were not very distinct, and the inferior wall of the slightly wide but not pathologically enlarged aditus was beautifully rounded. The picture in this projection thus did not show any changes indicating cholesteatoma, but a roentgenogram in RUNSTRÖM's 1st projection (Fig. 8) shows the antrum as an angular, distinctly circumscribed cavity with a calcareous linear zone towards the roof of the middle fossa of the skull. A diagnosis of cholesteatoma was accordingly considered not to be absolutely excluded, which consequently was erroneous.

If the cholesteatoma in the antrum is situated in a more or less pneumatized temporal bone, the difficulty of a roentgenological diagnosis may be just as great.

Should the cholesteatoma cavities be small, the Roentgen method of examination may prove a complete failure, provided there is not also a pathological enlargement of the aditus. Such a pathological enlargement may thus be the only change permitting a diagnosis of cholesteatoma in these cases.

If the destruction is large it may be difficult to differentiate between cholesteatoma and an abscess cavity unless the aditus is pathologically enlarged. From the point of view of the differential diagnosis it is generally pointed out that the margins of cholesteatoma cavities are as a rule more distinctly circumscribed than those of abscess cavities. Changes in sclerotic temporal bones also favour a cholesteatoma diagnosis. In addition, abscess cavities are not common, although occasionally met with in cases of chronic otitis. There are consequently no symptoms typical of one change or the other in the Roentgen picture, and cases therefore occur in which no certain roentgenological diagnosis can be set.

Cholesteatomata in the Attic

The material examined included 28 cases of cholesteatoma in the attic, of which 15 had produced changes visible in the Roentgen picture.

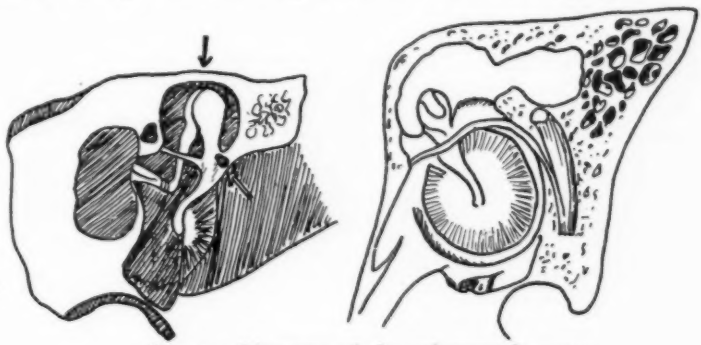

Fig. 9. Diagrams of the epitympanic recess.

The roentgenological changes differ with the localization of the cholesteatoma destructions in the epitympanic recess, and according to MAYER 3 fundamentally different types can be distinguished, as illustrated in the diagram (Fig. 9).

On the left is a frontal section through the external auditory canal and the tympanum, showing *inter alia* part of the tympanic membrane, the epitympanic recess with the ear-ossicles, and some cells of the lateral attic wall. The arrow in the external auditory meatus marks the place of

Fig. 10 a.

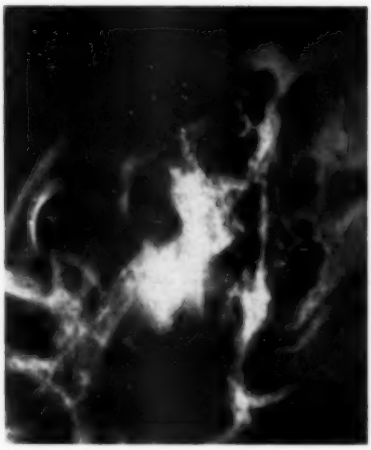

Fig. 10 b.

Fig. 10. *a*. Attic cholesteatoma with a destruction in the lateral wall. *b*. The healthy side of the same patient.

the attic fistulas, the arrow at the top the roof of the middle fossa of the skull.

On the right is a section parallel to the mastoid plane, showing the *tympanum*, *aditus ad antrum* and *antrum*. Some mastoid process cells can also be seen.

Fig. 11. Attic cholesteatoma producing a pathological enlargement of the aditus.

Cholesteatoma destructions occasionally appear in the lateral wall of the epitympanic recess, close to the fistula, and then produce very characteristic changes in the Roentgen picture in the form of a welldefined spikelike or rounded defect in the lower margin of the attic, which may vary considerably in size. Fig. 10 shows a typical change of this kind. It is most noticeable if compared with the opposite, healthy side.

In cases of cholesteatomata developing posteriorly towards the aditus the latter may become pathologically enlarged. In Fig. 11, showing a typical case of this kind, the well-defined

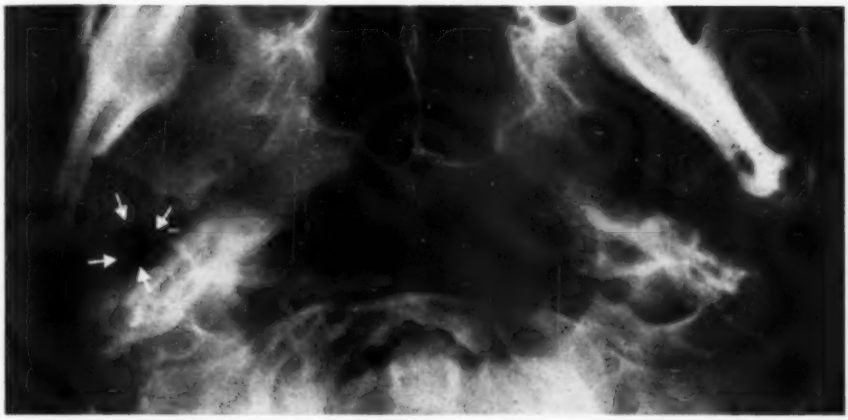

Fig. 12. Attic cholesteatoma with a destruction towards the roof of the middle fossa of the skull.

Fig. 13. Attic cholesteatoma with a destruction towards the roof of the middle fossa of the skull.

destruction, the margin of which is convex backwardly, can be seen to continue backwards towards the aditus, which is enlarged. Apart from the usure on the lateral and superior walls, the side of the posterior wall of the auditory canal is also planed down.

It must not be forgotten, however, that in these cases a high attic with smooth and even surfaces, in which there are no ear-ossicles, may look very like a cholesteatomatous attic.

Finally, cholesteatomata sometimes develop upwards towards the roof of the middle fossa of the skull and produce destructions there. In the axial picture, a distinctly circumscribed thinning is then discernible in

the place of the tympanum. We had 4 such cases in our material. Figs. 12 and 13 represent 2 typical examples. In all our cases remains of the ear-ossicles have shown up distinctly against the thinner part. There seems to be a general opinion that cholesteatoma will destroy the ossicles, and that the absence of these in a Roentgen picture favours the diagnosis cholesteatoma. In our experience this is not so, however, for while the ear-ossicles are absent in many cases of chronic otitis, they are, on the other hand, frequently found in cases of cholesteatoma, even when this is located in the attic, as shown in Figs. 12 and 13.

Complications

In 12 cases complications have been found by the operator, 10 times in the form of exposed patches of the dura and 3 times in the form of macroscopic usures on the semicircular canals. The exposed dura patches could in 2 of the cases be demonstrated in the Roentgen picture, and the canal usure in 1 case.

SUMMARY

The author describes the characteristic roentgenological cholesteatoma changes. He divides them, according to their localization, into cholesteatomata of the aditus ad antrum, antrum and attic. A new observation is that attic cholesteatomata causing destruction of the roof of the middle fossa of the skull can be observed in the axial picture.

ZUSAMMENFASSUNG

Verf. berichtet über die charakteristischen röntgenologischen Veränderungen der Cholesteatomhöhlen. Je nach der Lokalisation unterscheidet man Aditus-, Antrum- und Attikuscholesteatome. Als neue Beobachtung geht hervor, dass Attikuscholesteatome, die eine Zerstörung des Bodens der mittleren Schädelgrube geben, in der sog. axialen Aufnahme hervortreten.

RÉSUMÉ

L'auteur expose les signes radiologiques caractéristiques des cavités dues aux cholestéatomes. Selon leur localisation ceux-ci ont été classés en cholestéatomes de l'aditus, de l'antre ou de l'attique. Une nouvelle observation a résulté de ses recherches, à savoir que les cholestéatomes de l'attique qui entraînent une destruction du plafond du côté de la fosse cérébrale moyenne peuvent être reconnus sur l'image dite en projection axiale complète.

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AUS DEM »RADIUMHEMMET», STOCKHOLM (VORSTAND: PROF. ELIS BERVEN)

GERÄTE ZUR EINSTELLUNGSKONTROLLE AUF DEM GEBIETE DER RÖNTGENTHERAPIE[1]

von

Erik Lundström

Da tiefliegende Tumoren in zunehmendem Masse einer Röntgenbehandlung unterzogen werden, werden u. a. die Forderungen an die Genauigkeit der topographischen Analyse, ferner an die Möglichkeit die geeignetste Form und den geeignetsten Verlauf der Strahlenbündel festzustellen, sowie an die Kontrolle, dass diese Strahlenbündel während der Behandlung wirklich die beabsichtigte Lage einnehmen, gesteigert. Die topographische Analyse wird hauptsächlich mit der diagnostischen Röntgenapparatur durchgeführt, Form und Verlauf der Strahlenbündel werden in dem Bestrahlungsplan, gestützt auf die topographische Analyse, bestimmt. Die Kontrolle der Lage der Strahlenbündel im Körper kann in grossem Ausmasse während der Durchleuchtung und des Photographierens mit der Therapieröhre durchgeführt werden (HERRNHEISER, BERGLUND u. a.).

Diese Durchleuchtung erfordert aber teils im Hinblick auf die Abblendung der Strahlenbündel, teils bezüglich der Geräte, welche die Durchleuchtung und die Verbringung des Patienten in die gewünschten Lagen ermöglichen, spezielle Vorrichtungen. Die Abblendungsgeräte, welche angewandt werden, müssen u. a. so beschaffen sein, dass sie den Untersucher in grösstmöglichem Ausmasse sowohl gegen die primäre als auch sekundäre Röntgenstrahlung schützen. Die tubenförmigen Blenden haben sich in vielen Hinsichten als für diesen Zweck besonders geeignet erwiesen.

Um eine Durchleuchtung des Patienten mit der Therapieröhre im Liegen zu ermöglichen, muss, falls sich die Röntgenröhre über dem Patienten befindet, ein Durchleuchtungsschirm unter dem Patienten, vor der Austrittsstelle des Strahlenbündels, angebracht werden können.

[1] Bei der Red. am I. IV. 1944 eingegangen.

Ausserdem sind spezielle Vorrichtungen erforderlich, damit das Bild auf dem Durchleuchtungsschirm bequem beobachtet werden kann.

Abb. 1 zeigt einen einfachen Zusatztisch zu einem in Schweden häufig angewandten Bestrahlungstisch[1], das zur Durchleuchtungskontrolle dienen soll. Die Tischplatte besteht aus zwei im Winkel zusammengeleimten Brettern und hat somit die Form einer Rinne. Hierdurch wird teils eine beträchtliche Stabilität der Tischplatte erreicht, teils liegt der Patient sicher und ausserdem bequem, trotz der harten Unterlage. Auf den Durchleuchtungsbildern entsteht kein störender Schatten der Tischplatte, da die Winkelstellung zwischen den beiden Hälften der Tischplatte die Anwendung von ziemlich dünnem Material ermöglicht. Unter der rinnenförmigen Tischplatte befindet sich eine in der Querrichtung in einem Falz an den seitlichen Stützen des Tisches verschiebbare Platte. Bei Durchleuchtung von oben, wird auf dieser Platte ein Durchleuchtungsschirm mit der lichtempfindlichen Schicht nach oben nur durch gewöhnliches Glas geschützt, angebracht. Das Bild auf dem Durchleuchtungsschirm wird in der Ebene beobachtet, auf welche die Röntgenstrahlen fallen. Auf Grund des rinnenförmigen Tisches ist der Einblick unter den Tisch erleichtert, sollte dieser nicht zufriedenstellend sein, so wird der Schirm unbedeutend mehr gegen den Beobachter geneigt, was einen besseren Überblick über das Bild auf dem Schirm ermöglicht (vgl. Abb. 2). Um den Untersucher zu schützen, wird das Strahlenbündel durch eine Bleiplatte aufgefangen, die an der Rückseite des Durchleuchtungsschirmes angebracht ist. Die Sekundärstrahlung, ausgehend vom Patienten, wird mittels einer Bleiglasplatte abgeschirmt, die an der Kante des Durchleuchtungsschirmes beweglich befestigt ist, welche gegen den Untersucher gewandt ist. Werden ausserdem Schutzhandschuhe und eine Schutzschürze angewandt, so dürften hoch gestellte Anforderungen an den Strahlenschutz erfüllt sein. Die Durchleuchtung wird selbstverständlich mit einer so niedrigen Belastung der Röhre als möglich vorgenommen.

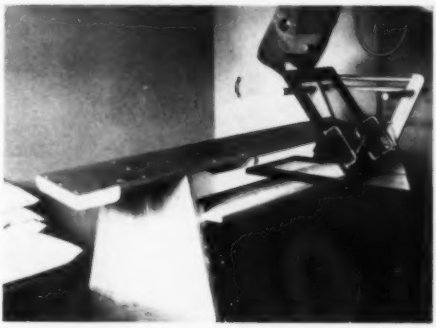

Abb. 1.

Bei Strahlenrichtungen in der Nähe der Horizontalebene geht man von dem beschriebenen Durchleuchtungsschirm zu einem gewöhnlichen derartigen Schirm mit Bleiglas zwischen dem Untersucher und der licht-

[1] Fabrikat AB Järnh, Stockholm.

empfindlichen Schicht über. Hierbei wird die Platte unter dem Tisch so weit auf die Seite herausgezogen, dass die untere Kante des Durchleuchtungsschirmes auf dieselbe gestützt werden kann (s. Abb. 3).

Am Kopfende des Tisches ist eine Stütze für die Hände und Arme des Patienten angebracht, und zwar für den Fall, dass Seitenfelder über dem Thorax angewandt werden, wobei die Arme nach oben gehalten werden müssen.

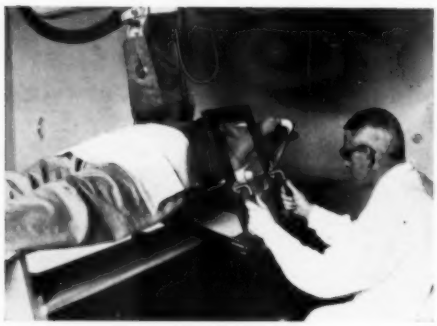

Abb. 2.

Der Bestrahlungstisch für welchen die Anwendung dieses Zusatztisches beabsichtigt ist, hat einen in allen horizontalen Richtungen beweglichen Oberteil. Da der Zusatztisch auf diesem Oberteil angebracht wird, können dessen Bewegungen verwendet werden, was die Arbeit in hohem Grade erleichtert.

Abb. 3.

Wie bereits erwähnt, wird die Durchleuchtung angewandt um die Lage des Strahlenbündels im Körper zu kontrollieren, nachdem ein Bestrahlungsplan aufgestellt wurde. Dies ist besonders dann wichtig, wenn eine Kompression zur Anwendung kommt, da dann oft Schwierigkeiten vorliegen, dem Bestrahlungsplan exakt zu folgen.

Man kann auch in geeigneten Fällen direkt, ohne sich auf einen vorher aufgestellten Bestrahlungsplan zu stützen, mittels einer Durchleuchtung mit der Therapieröhre die Lage der geeignetsten Einfallsfelder und die Richtung der Zentralstrahlen feststellen. Dieses Verfahren wurde u. a. bei der Behandlung von Ösophaguskarzinom angewandt, musste aber durch Herddosenmessungen oder Tiefenbestimmungen komplettiert werden.

Als Beispiel für den Wert der Durchleuchtung mit der Therapieröhre kann die Behandlung des Hypopharynxkrebses genannt werden. In diesem Falle ist es wichtig, dass das Halsrückenmark vor Strahlenschädigungen geschützt wird, weswegen sich die Aufgabe ergibt, sämtliche

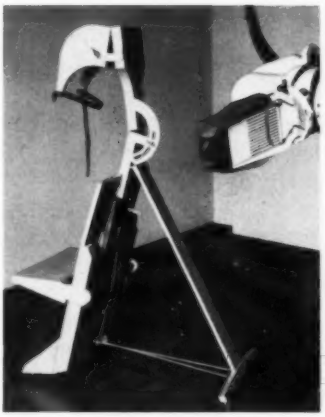

Abb. 4.

Abb. 6.

Strahlenbündel so zu verlegen, dass sie nicht das Halsrückenmark umfassen. Zu diesem Zwecke wurde ein Stuhl (s. Abb. 4) mit einer Fixationsanordnung für den Kopf und den Hals konstruiert, welche im Verhältnis zum Rumpf in eine solche Lage verbracht werden, dass die normale Lordose der Halswirbelsäule ausgeglichen wird. Durch eine Anordnung zur Neigung des ganzen Stuhles wird hernach die Halswirbelsäule vertikal eingestellt, was unter Durchleuchtung geschehen kann. Hierdurch werden die Winkeleinstellungen erleichtert, da in der Regel die Winkelskalen des Behandlungsstatives in der Horizontal- und Vertikalebene liegen. Hierauf werden die Halskonturen mittels eines Gipskragens abgegossen und auf Papier aufgezeichnet (s. Abb. 5). Nachdem die Lage der wichtigsten Halsorgane innerhalb der genannten Kontur angegeben worden ist, wird der Verlauf der Strahlenbündel aufgezeichnet und die Grenzen für deren Einfallsfeld wird auf die Haut mit Hilfe des Gipskragens überführt.[1] In der letzten Zeit wurde im »Radiumhemmet» ein vorderes und ein hinteres Einfallsfeld auf jeder Seite des Halses angewandt, wobei die Zentralstrahlen des Strahlenbündels gegen den zentralen Teil des Tumorgebietes gerichtet wurden. Die hintere Front aller Strahlenbündel wurde vor das Halsrückenmark verlegt und

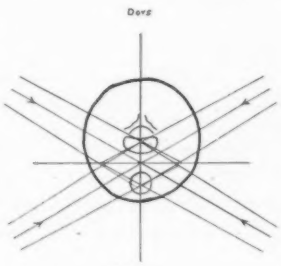

Abb. 5.

[1] Verf. hat eine ausführlichere Schilderung über die Aufstellung von Behandlungsplänen in Acta radiologica XXIV, S. 462—468 gegeben.

als Ausgangspunkt für die Orientierung wurden die hinteren Flächen der Wirbelkörper der Halswirbelsäule angewandt. Mit Hilfe der in den Bestrahlungsplan gefundenen Winkelwerte für die Richtung der Zentrahlstrahlen im Verhältnis zur Sagittal- oder Fontalebene, wird die Röntgenröhre preliminär eingestellt, worauf eine Feinkorrektion unter Durchleuchtung vorgenommen wird, so dass die hintere Grenze des Strahlenbündels in das Gebiet der hinteren Ebene der Wirbelkörper fällt (s. Abb. 6).

Die Einstellung während der Durchleuchtung sowie die Röntgenbehandlung selbst, werden in hohem Grade durch eine für die Röntgenbehandlung des Hypopharynx speziell konstruierte Tubenblende mit einer vierkantigen, in allen Richtungen variierbaren Öffnung, erleichtert. Zwei entgegengesetzte, bewegliche Wände der Blende sind mit parallel in einander verfalzten Lamellen versehen, die zur Abgrenzung des Feldes auf die Haut heruntergeschoben werden können. Die beiden übrigen Feldgrenzen werden mittels beweglichen, aus Bleiplatten hergestellten Giebeln an der Blende abgeschirmt (s. Abb. 4). Eine im Prinzip gleiche Konstruktion wurde bei einer Blende, die zur Röntgenbehandlung von Tumoren im Thorax bestimmt war, angewandt.[1] Man erhält mit diesem Blendentypus gute Möglichkeiten für eine Feldvariation und kann ausserdem die Konturen der Blendenöffnung zur Erleichterung der folgenden Einstellungen leicht auf der Haut abzeichnen.

ZUSAMMENFASSUNG

Verf. hebt hervor, wie wertvoll es ist, mittels der Therapieröhre zur Kontrolle der Lage des Strahlenbündels innerhalb des Körpers zu durchleuchten und gibt die Konstruktion eines Zusatztisches für ein Bestrahlungstisch zur Durchleuchtung in liegender Stellung sowie einen Stuhl mit Kopfstütze, ferner eine Blende zur Röntgenbehandlung von Hypopharynxkarzinom an.

SUMMARY

The present author emphasizes the value of transillumination by means of the therapeutic tube for control of the position of the ray bundles within the body. Furthermore, he describes the construction of an additional leaf to a treatment table for transillumination in a recumbent position, as well as a chair with a head support, and a diaphragm for the Röntgen treatment of cancer hypopharyngis.

RÉSUMÉ

L'auteur souligne l'importance d'un examen par transparence au moyen du tube thérapeutique pour le contrôle de la position des faisceaux de rayons dans l'interieur du corps. Aussi, il indique la construction d'un pliant de la table de traitement pour l'examen par transparence dans la position étendue, et une chaise à l'appui de tête, et ensuite un diaphragme pour la traitement au Rayons Röntgen du cancer hypopharyngis.

[1] Die Blende wurde vom Verf. in Acta radiologica XXIV, S. 259—262 beschrieben.

FROM THE RADIUM CENTRE, COPENHAGEN (CHIEF: JENS NIELSEN, M. D.)

A SINGULAR CASE OF THE PLUMMER-VINSON SYNDROME[1]

by

Aage Videbæk

In 1914, PLUMMER described a dysphagia to which he affixed the adjective: hysterical. KELLY (1919) expressed the belief that the affection was not hysterical, but that the disturbance of the mechanism of deglutition was due to a hyperesthesia owing to organic changes; because he in his patients found fissures at the commissures of the lips and in many also muscular spasm and mucosal changes in the esophagus. PATERSON (1919) added to the clinical picture the symptoms glossitis and anemia; and in 1922 VINSON published a survey of 69 cases, 57 of them female, all of which had as common features dysphagia and anemia. Roentgen examinations failed to show any changes in the esophagus, and also esophagoscopy showed normal conditions in that organ. Twelve of the sixty-nine had enlarged spleen. It is agreed that after the condition has been present for a long time irreversible changes may occur in the mucosa, and several investigators have demonstrated mucosal webs. Necropsy findings are, of course, rare; but they have been described by SUZMANN, who in an esophagus found hyperkeratosis and in spots atrophic degeneration. In another case which came to necropsy MCGEE & GOODWIN found chronic esophagitis and small ulcerations in all parts of the organ. Occasionally there may probably also on this basis develop carcinoma, as pointed out by AHLBOM, who thinks that the Plummer-Vinson syndrome is very common in female patients with cancer of the mouth, throat or esophagus and often a percursor of that disease. Examinations of the rather considerable number of cancer patients who pass through the Radium Centre in Copenhagen do not, however, confirm that view. From observations here there is no reason to believe that the Plummer-Vinson syndrome is common; but lack of acquaintance with it may no doubt sometimes lead to mistaken diagnoses such as cancer of the esophagus or hysterical dysphagia.

[1] Submitted for publication Dec. 1, 1943.

WALDENSTRÖM & KJELLBERG give the syndrome a prominent place among the dysphagies and describe in great detail the radiologic features of the condition, which they find to be specific for it. They stress the importance of the exposure, after contrast swallow, of the *dilated* esophagus, indicating a special technic by which they are able to demonstrate the changes that occur, from quite slight to more pronounced, oftenest just below the cricoid cartilage, but never below the arch of the aorta. They are usually visible only on the lateral views, where they appear as a smooth defect in the shadow, at right angles from the wall, exactly alike in all the pictures. A case in which there was retention above the cardia is described, however, by HANSEN & HENILD.

The Plummer-Vinson syndrome was formerly considered as a pathologic picture by itself, and the anemia as a simple result of the difficult deglutition (insufficient feeding). But WITTS saw that the anemia might recur also after the dysphagia had disappeared, and therefore believes that it is not due to the latter. After attention had been directed to mucosal changes, perlèche, atrophy of the lingual papillae, chilitis, koilonychia and achylia, slight phenomena of this kind were found in cases of essential hypochromic anemia. Besides, the difficulty of deglutition very often ceases after an intensive ferrotherapy, less readily, of course, if the changes after long-lasting dysphagia have become irreversible. There can thus be no doubt about the connexion between the dysphagia and the essential hypochromic anemia; both symptoms are probably secondary in relation to the existing achylia.

It is still not clear whether the fissures at the corners of the mouth are expressions for an ariboflavinosis. In contrast to HANSEN & HEINILD'S experience with 1 case, BICHEL & MEULENGRACHT saw in 4 cases good healing of these fissures after treatment with riboflavine. The former believe that the fissures are the result of maceration of saliva in the furrows formed in the corners of the mouth only as the result of the atrophy of the lips.

The following classic case of the Plummer-Vinson syndrome, presenting several singular features, was recently seen at the Radium Centre.

The patient was a woman, Marie P. (Case record no. 30609), 60 years old. No anemia in the family. No rheumatic fever; no tuberculosis. Venerea denied. Five normal childbirths. She had always menstruated regularly up to her fiftieth year, when her bleedings became profuse. During a stay in hospital she was then found to be anemic, and she was sterilised by roentgen. Since then there have been no vaginal hemorrhages. No dyspepsia; no cardialgia. Defecation and micturation normal. She suffers from moderate functional dyspnea and in cold air from short spells of pricking precordial pain, which disappear by rest. Never any edemas. Has had complete dental prosthesis for about twenty years.

She consulted a physician for pricking pain at the back of the throat when swallowing, which she can only do after several attempts. She cannot swallow meat at all, and bread and potatoes only with difficulty. This condition has lasted for about ten years, during

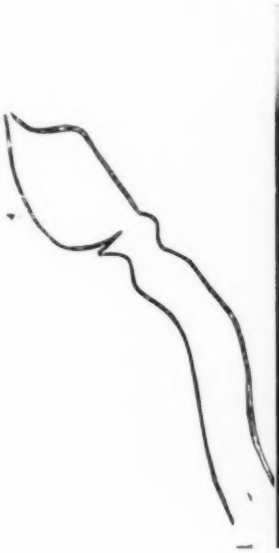

Fig. 1.

Fig. 2.

which time she has also been anemic and had fissures at the corners of the mouth, and her nails have had a tendency to become brittle and ragged. The condition has on the whole been somewhat intermittent. Her weight went down, during this period, from 64 to 54 kg. For the anemia she was for a short time treated with iron, which had no effect on the other symptoms. The dysphagia was believed to be functional, but as it now had become worse her panel doctor had a *roentgen examination* made of her esophagus (May 10th, 1943).

After she had been made to swallow some barium porridge there was 4 cm. above the jugulum seen (Fig. 1) a dilatation, and below this a stricture, about 0.5 cm. long, with a lumen of about threefourths of a centimeter. The outline of the stricture, as well as a narrow defect, about 5 mm. long, starting at almost right angles from the anterior wall close to the upper limit of the latter, were very constant.

As the result of the roentgen examination did not exclude the possibility of a tumor, the patient was in May, 1943, referred to the Radium Centre, where the findings were as follows: Height, 159 cm., weight, 54.2 kg. She is small, grey-haired, thin, pale and worried-looking, but makes a normal impression psychically. There are fissures at the corners of the lips, and she is slightly »carp-mouthed». The tip and edges of the tongue show marked atrophy of the papillae, and the atrophic mucous membrane is in these places the seat of small coatings; the papillae on the dorsum perhaps a little lower than normal. The tongue is not tender. The mucous membrane on the posterior wall of the hypopharynx is somewhat granulated; otherwise nothing abnormal there. The nails are striated, lamellar, rather soft, flat or concave. There are no swellings of the lymph nodes on the neck, nor any other peripheral adenitis. The thyreoid gland is not palpably enlarged. Stethoscopy of the lungs and heart, normal. The spleen not palpable. No edemas. Roentgen examin-

ation of the heart shows slight, diffuse enlargement; the transverse diameter 12 cm. Interior breadth of the thorax, $22^1/_2$ cm. Electrocardiogram, normal.

It is attempted to introduce an esophageal bougie, but it can only be carried down to 20 cm. from the dental margin.

Hemoglobin, 71 per cent. Red blood corpuscles, 4,330,000 per cubic millimeter. Color index, 0.82. Leucocytes, 4360; neutrophile rod forms, 1 per cent; neutrophile polymorphonucleated 67 per cent; eosinophils, 4 per cent; basophils 0.5 per cent; monocytes, 11.5 per cent; lymphocytes, 16 per cent. Serum iron, 52γ per cent; serum ascorbic acid, 0.15 mg. per cent. Gastric achylia demonstrated.

As the condition from the roentgenologic picture and the whole clinical examination was considered to be in all probability a case of Plummer-Vinson syndrome, the patient was admitted to the medical service of the Finsen Institute, and was treated with iron intravenously and by mouth, besides which she was given vitamin B (Becoplex intramuscularly and by mouth). Under this treatment the swallowing became somewhat easier, and also in the koilonychia and the fissures there was some improvement.

As the presence of the Plummer-Vinson syndrome made it reasonable to inspect the mouth, pharynx and esophagus for possible cancer, *esophagoscopy* was made, June 20th, 1943. Twenty centimeters from the dental margin a constriction was encountered, consisting of longitudinally running, smooth, trabecular projections on the right lateral wall, and between them large varices were seen shining through. The lumen of the esophagus was in this place only as large as a little finger, and it was impossible for the esophagoscope to pass through. For safety's sake a biopsy was made (K. ROSENQUIST). *Microscopy* of the excised tissue (FR. BANG) showed it to consist only of a blood clot and scrapings of regular pavement epithelium. There were no signs of cancer.

After the patient had now for a month had intensive treatment with iron, another *roentgen examination of the esophagus and larynx* was made on June 28th (Fig. 2). On examination of the esophagus there was in the side view seen in the latter an air bubble extending up to the level of the 7th cervical vertebra. The deglutition was rather difficult, inasmuch as the patient could swallow only quite small mouthfuls. The ingested barium porridge stopped 2 cm. above the jugulum, and here a dilatation was seen, and the diameter of the esophagus was $2^3/_4$ cm. Below it the lumen narrowed to 3 mm. in diameter, and this diameter continued all the way down to a level with the upper part of the aortic arch; only below that point were there normal mucosal folds. The contours of the stenosis were fairly smooth and sharp; but in a few places there were small indentations. It was thought that the changes were most likely expressions for the presence of a tumor (B. WORNING).

A *second esophagoscopy* was therefore done on July 9th. Twenty-two cm. from the dental margin a stricture of diaphragmatic appearance was encountered, in which were seen two small openings, separated by a fold of mucous membrane. No actual tumor was seen, but the mucosa above the diaphragm was somewhat folded, and the esophagus there somewhat dilated. A *biopsy* was made from the area between the two openings. This made the mucosal fold disappear, and the area was transformed into one lumen; through which it was still impossible to pass the esophagoscope, but a sound and a forceps passed easily (O. STRANDBERG).

Microscopy: Small bits of tissue, the surface of which is covered with a thickened pavement epithelium of several layers, whose cells are not, however, altered in type. Underneath it a highly vascularised, fibrous tissue, which in places has almost the appearance of granulation tissue with massive, diffuse infiltration of round- or plasma cells and many leukocytes. No signs of cancer or specific inflammation. (H. GORMSEN).

After the membrane had been cut through a remarkable change took place in the patient's condition: she could now eat roast meat; what she had not been able to do for

many years. A roentgen examination immediately after the esophagoscopy still showed stricture in the same place, with retention in the epiglottic valleculae and the piriform recess, but without any distinct accumulation above the stenosis.

The treatment with ferrotartrate had been kept up all the time, and as a result the hemoglobin percentage had by July 20th risen to 90, the color index to 0.96. The serum iron was 38 γ per cent. A bougie treatment was instituted, and after a month a no. 42 passed readily and she swallowed with perfect ease. The condition of the tongue was as before, and the fissures almost the same. A *roentgen examination of the esophagus* on Aug. 3rd showed entirely normal conditions. The patient still comes to control; the deglution is quite free and during the treatment she has gained 10 kg. in weight.

We thus have here the case of a woman, 60 years old, who for about 10 years has suffered from dysphagia, and who presented the typical Plummer-Vinsons syndrome, inasmuch as she, besides, was in a state of hypochromic anemia with low serum iron, had fissures at the corners of the mouth, spoon-nails, and suffered from achylia. Moreover, there were, as roentgenologic features, membranous constriction in the upper part of the esophagus, with dilatation above it; and retention in the piriform recess and the epiglottic valleculae.

What makes the case interesting is the rather low situation of the stricture, at the height of the clavicle, the esophagoscopic finding of a membranous string across the cavity (the microscopy of an excised piece from which is probably the first of its kind published) and the sudden improvement of the patient's condition as soon as this membrane had been cut through. After this she was completely cured of her dysphagia by bougienage, the administration of thiamine and riboflavine and intensive treatment with divalent iron by mouth or intravenously. The roentgenologic picture of the esophagus became entirely normal, she became less anemic, the state of her nails improved considerably. The effect on the fissures at the corners of the mouth was moderate; only the atrophy of the lingual papillae persisted unchanged.

SUMMARY

After briefly discussing the pathogenesis of the diverse symptoms constituting the Plummer-Vinson syndrome, the author reports a typical case of the latter in a woman, 60 years old, who for ten years had suffered from dysphagia and anemia. A singular feature of it was the esophagoscopic finding of a membranous string across the esophagus at the height of the stricture, which was situated unusually far down, at the level of the jugulum. Biopsy from this showed hyperkeratosis and chronic inflammation. When the membrane had been cut through the patient's condition suddenly improved, and she was finally cured by the classic means of bougienage and ferrotherapy.

ZUSAMMENFASSUNG

Nachdem Verf. die Pathogenese der verschiedenen Symptome, aus denen das Plummer-Vinson'sche Syndrom besteht, kurz besprochen hat, gibt er einen typischen Fall dieser Krankheit bei einer 60jährigen Frau wieder, die seit 10 Jahren an Schluckbe-

schwerden und Anämie gelitten hatte. Bemerkenswert war der ösophagoskopische Nachweis eines membranösen Bandes, das in der Höhe der ungewöhnlich niedrig, am Jugulum gelegenen Striktur die Speiseröhre durchkreuzte. Biopsie dieses Bandes ergab Hyperkeratose und chronische Entzündung. Nach Durchschneidung der Membran besserte sich der Zustand der Kranken plötzlich, und durch die klassische Behandlung mit Sondierung und Eisen wurde sie endgültig geheilt.

RÉSUMÉ

Après une brève discussion de la pathogénie des divers symptômes constituant le syndrome de Plummer-Vinson l'auteur en rapporte un cas typique chez une femme de 60 ans, qui pendant dix ans avait souffert de dysphagie et d'anémie. Un trait singulier à relever chez elle était l'existence, découverte à l'œsophagoscopie, d'une bride membraneuse, en traves de l'œsophage, à la hauteur du rétrécissement, lequel était situé plus bas que d'habitude au niveau du jugulum. Une biopsie montra de l'hyperkératose et une inflammation chronique. Une fois la membrane sectionnée l'état de la malade s'améliora subitement et elle fut définitivement guérie par les moyens classiques du bougirage et de la thérapeutique martiale.

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